PL-78-0175

ARBRL-CR-356

BRL

CONTRACT REPORT ARBRL-CR-356

THREE-DIMENSIONAL COMPUTATIONS,

VOLUME IV: 77.5° OBLIQUE IMPACT

Prepared by

Computer Code Consultants
527 Glencrest Drive
Solana Beach, CA 92075

December 1977

USA ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
USA BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER CONTRACT REPORT ARBRL-CR-356	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* THREE-DIMENSIONAL COMPUTATIONS, VOLUME IV: 77.5° OBLIQUE IMPACT		5. TYPE OF REPORT & PERIOD COVERED Final, April 1976-April 1977
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) W. Johnson V. Kucher (BRL)		8. CONTRACT OR GRANT NUMBER(s) DAAD05-76-C-0755
9. PERFORMING ORGANIZATION NAME AND ADDRESS Computer Code Consultants 527 Glencrest Drive Solana Beach, CA 92075		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 1W161102A33H
11. CONTROLLING OFFICE NAME AND ADDRESS USA Ballistic Research Laboratory Aberdeen Proving Ground, MD 21005		12. REPORT DATE DECEMBER 1977
		13. NUMBER OF PAGES 73
14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)* US Army Materiel Development & Readiness Command 5001 Eisenhower Avenue Alexandria, VA 22333		15. SECURITY CLASS. *(of this report)* UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Penetration mechanics
Hypervelocity impact
Hydrodynamic computer code
Three-dimensional computer code
Eulerian computer code

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Numerical calculations were made in 1975 of four oblique impact problems: 30°, 45°, 60°, and 77.5°. A graphical display of the results of the 77.5° impact of a copper jet on a steel target are presented.

DD FORM
1 JAN 73 **1473** EDITION OF 1 NOV 65 IS OBSOLETE

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

I. INTRODUCTION

A series of four oblique impact computations (30°, 45°, 60°, and 77.5°) involving a copper jet impacting a steel plate were completed in 1975 for the Ballistic Research Laboratory.[1] This work was performed using TRIDORF[2] and DORF[3,4] and ancillary programs CUBIT[3] and ADJUST[4] under Contract No. DAAD05-75-C-0738.

The effort for 1976 has been directed towards a graphical display of the data from these computations. The four oblique impacts in the series are presented in sequential volumes[5,6,7] with the results of the 77.5° obliquity impact being reported here.

II. DESCRIPTION OF THE PROBLEM

The 77.5° oblique impact computation involved a copper jet with a 0.7086-mm radius impacting on a 12.7-mm thick steel target. The obliquity angle is measured between the normal to the target and the axis of the jet. Since TRIDORF uses a retangular grid, the copper jet was treated as a bar with a square cross section of 1.256-mm width, thus preserving the cross-sectional area of the jet. The impact velocity was 7.55 km/s.

The Tillotson[8] form of the equation of state was used for the computations.

1. W. E. Johnson, "Three-Dimensional Computations on Penetrator-Target Interactions," Ballistic Research Laboratory Contractor Report No. 338, May 1977. (AD #A041058)

2. W. E. Johnson, "TRIDORF - A Two-Material Version of the TRIOIL Code with Strength," Computer Code Consultants, CCC-976, September 1976.

3. W. E. Johnson, "Code Correlation Study," Air Force Weapons Laboratory Report No. AFWL-TR-70-144, April 1971.

4. W. E. Johnson, "Development and Application of Computer Programs to Hypervelocity Impact," Systems, Science and Software, 3SR-749, July 1971.

5. W. E. Johnson and V. Kucher, "Three-Dimensional Computations, Volume I: 30° Oblique Impact", Ballistic Research Laboratory Contractor Report No. 344, July 1977. (AD #A043295)

6. W. E. Johnson and V. Kucher, "Three-Dimensional Computations, Volume II: 45° Oblique Impact", Ballistic Research Laboratory Contractor Report.No. 354, November 1977.

7. W. E. Johnson and V. Kucher, "Three-Dimensional Computations, Volume III: 60° Oblique Impact", Ballistic Research Laboratory Contract Report ARBRL-CR-355, December 1977.

8. J. H. Tillotson, "Metallic Equations of State for Hypervelocity Impact," Gulf General Atomic, GA-3216, July 1962.

A view of a three-dimensional grid is shown in Figure 1. Each cell is identified by the coordinates (I,J,K), which number the cells in the x,y,z-directions, respectively. The overall size of the computational grid was x = 19.884 mm by y = 55.596 mm by z = 8.367 mm. The maximum number of cells in the x-direction was I = 36, in the y-direction, J = 60, and in the z-direction, K = 15. The total number of cells in the grid was 32,400. Table I presents the dimensions of the cells, DX, DY, and DZ, and the grid coordinates as shown in Figure 1. These data are displayed in Figure 2.

The xy-plane was used as a plane of symmetry through the bar in order to keep the number of computational cells at a minimum. Since the width of the bar was four cells, the bar was two cells wide from the plane of symmetry. Figure 3 shows the penetrator-target configuration as it is located in the computational grid.

III. GRAPHICAL RESULTS

The numerical output of the computations is presented as density and pressure fields. The density and pressure are plotted on a two-dimensional spatial plane having the coordinates corresponding to the centers of cells. The fields are plotted such that a cell-number coordinate is held constant. For example, K may be constant meaning that the density or pressure is being presented for the cells between two z-planes bounding the K-cells. These bounding planes will be indicated in each figure. Figures 2 and 3 should be useful for orienting oneself in the grid.

The density scale for the density field plots can be realized from the initial density of the jet and the target, 8.9 and 7.8 Mg/m^3, respectively. The density scale is the same in all the density field plots.

The pressure scale is not the same in all the pressure field plots; therefore, the maximum pressure, Pmax, is indicated on each figure.

The first set of figures, Figures 4-18, shows the density and pressure fields at a constant time of 1.55 μs for various K-slabs which are numbered from the plane of symmetry. The jet appears distinct only when K = 1 and K = 2 since, initially, the jet was two cells in width from the plane of symmetry.

The second set of figures, Figures 19-32, shows the density and pressure fields at a constant time of 2.23 μs for various K-slabs. Data for K = 12 could not be recovered from the magnetic output tapes for plotting.

The third set of figures, Figures 33-45, shows the density and pressure fields at a constant time of 2.65 μs for various K-slabs.

8

Data for K = 3 and K = 6 could not be recovered from the magnetic output tapes for plotting. Another view of the corresponding figures in the third set of figures is shown in Figures 46-58. Also, three views of of the density field at 2.65 µs for K = 1 are shown in Figure 59.

A comparison of the density and pressure fields at K = 1 for various times is shown in Figures 60-61.

IV. SUMMARY

Numerical computations were made in 1975 of oblique impact problems. A graphical display of the results of the 77.5° impact of a copper jet on a steel target are presented for future analysis. The results for the 30°, 45°, 60°, and 77.5° oblique impacts are presented in sequential volumes.

Table I. Grid Coordinates and Cell Dimensions

| I	x (mm)	DX (mm)	J	y (mm)	DY (mm)	K	z (mm)	DZ (mm)
1	2.172	2.172	1	6.379	6.379	1	0.314	0.314
2	3.672	1.500	2	9.874	3.495	2	0.628	0.314
3	4.672	1.000	3	11.674	1.800	3	0.942	0.314
4	5.372	0.700	4	13.274	1.600	4	1.256	0.314
5	5.872	0.500	5	14.674	1.400	5	1.601	0.345
6	6.372	0.500	6	15.874	1.200	6	1.981	0.380
7	6.872	0.500	7	16.874	1.000	7	2.399	0.418
8	7.372	0.500	8	17.674	0.800	8	2.859	0.460
9	7.872	0.500	9	18.274	0.600	9	3.365	0.506
10	8.372	0.500	10	18.774	0.500	10	3.921	0.556
11	8.872	0.500	11	19.174	0.400	11	4.540	0.619
12	9.372	0.500	12	19.488	0.314	12	5.213	0.673
13	9.872	0.500	13	19.802	0.314	13	5.953	0.740
14	10.372	0.500	14	20.116	0.314	14	6.767	0.814
15	10.872	0.500	15	20.430	0.314	15	8.367	1.600
16	11.372	0.500	16	20.744	0.314			
17	11.686	0.314	17	21.058	0.314			
18	12.000	0.314	18	21.372	0.314			
19	12.314	0.314	19	21.686	0.314			
20	12.628	0.314	20	22.000	0.314			
21	12.942	0.314	21	22.314	0.314			
22	13.256	0.314	22	22.628	0.314			
23	13.570	0.314	23	22.942	0.314			
24	13.884	0.314	24	23.256	0.314			
25	14.384	0.500	25	23.570	0.314			
26	14.884	0.500	26	23.884	0.314			
27	15.384	0.500	27	24.198	0.314			
28	15.884	0.500	28	24.512	0.314			
29	16.384	0.500	29	24.857	0.345			
30	16.884	0.500	30	25.237	0.380			
31	17.384	0.500	31	25.655	0.418			
32	17.884	0.500	32	26.115	0.460			
33	18.384	0.500	33	26.621	0.506			
34	18.884	0.500	34	27.177	0.556			
35	19.384	0.500	35	27.796	0.619			
36	19.384	0.500	36	28.596	0.800			
			37	29.396	0.800			
			38	30.196	0.800			
			39	30.996	0.800			
			40	31.796	0.800			
			41	32.596	0.800			
			42	33.396	0.800			
			43	34.196	0.800			
			44	34.996	0.800			
			45	35.796	0.800			
			46	36.596	0.800			
			47	37.396	0.800			
			48	38.196	0.800			
			49	38.996	0.800			
			50	39.796	0.800			
			51	40.596	0.800			
			52	41.396	0.800			
			53	42.196	0.800			
			54	42.996	0.800			
			55	43.796	0.800			
			56	44.596	0.800			
			57	45.396	0.800			
			58	46.196	0.800			
			59	49.396	3.200			
			60	52.596	3.200			

10
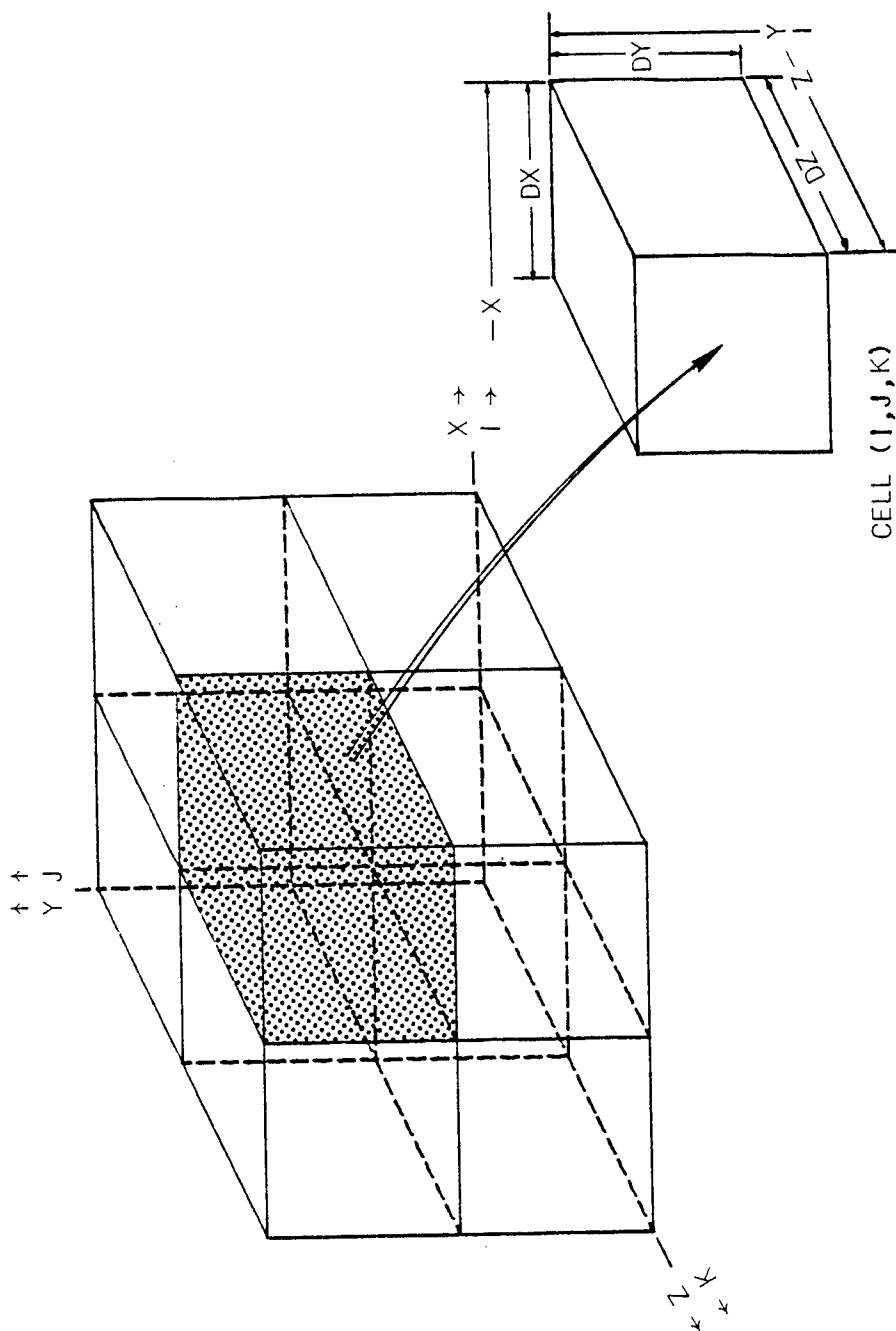
Figure 1. A Three-Dimensional Grid
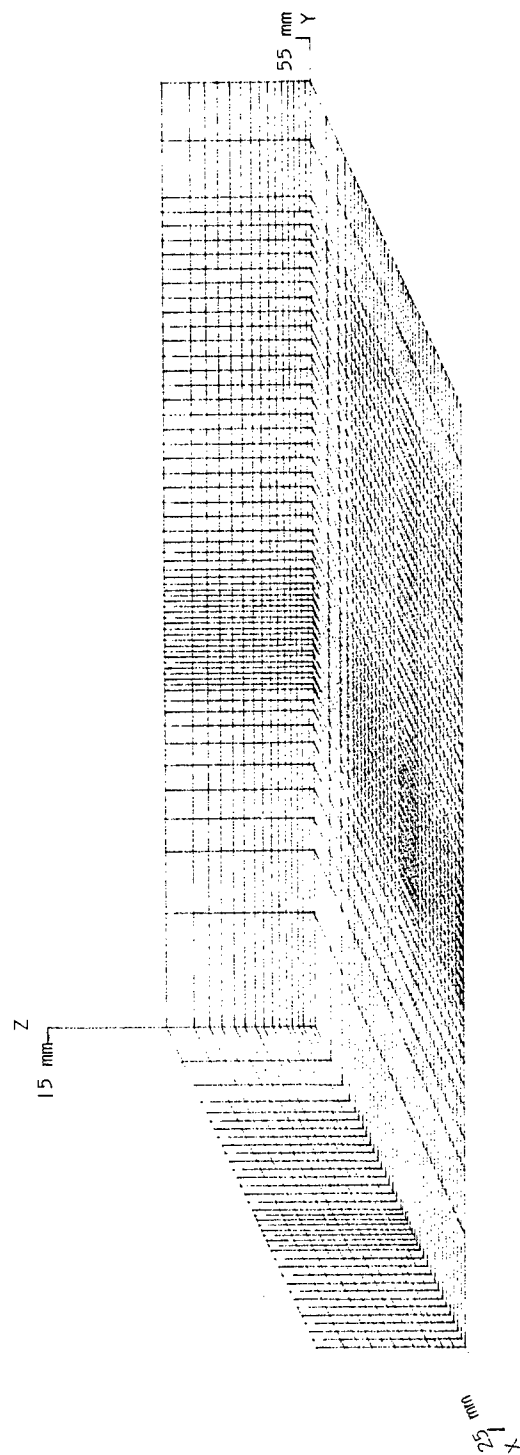
Figure 2. Computational Grid

12
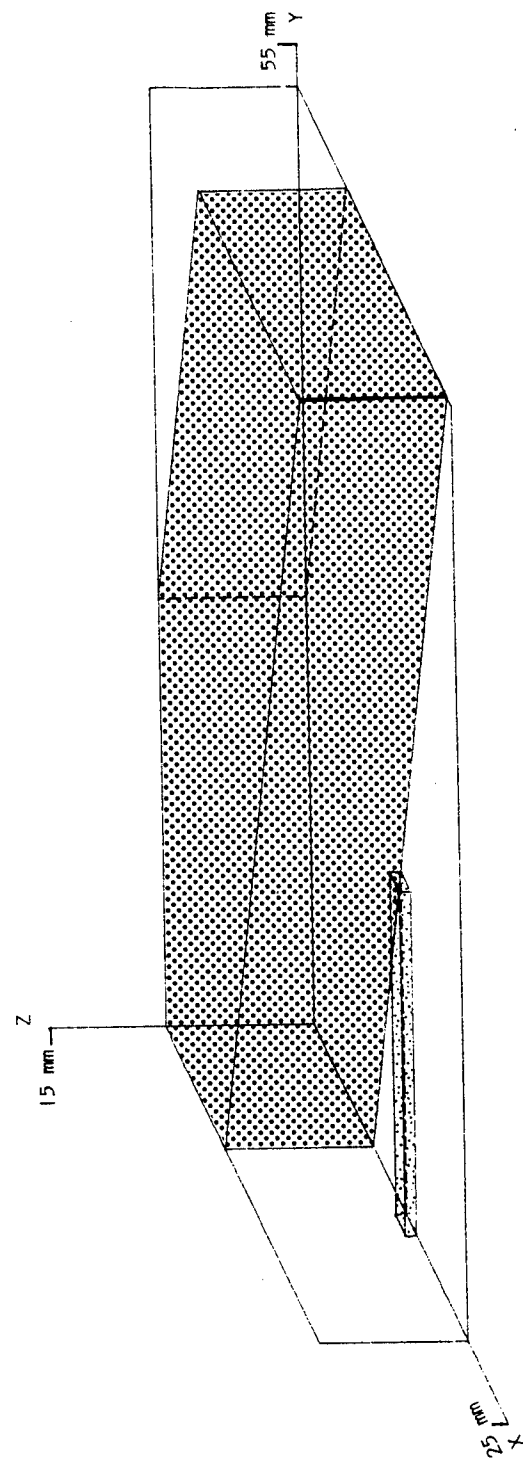
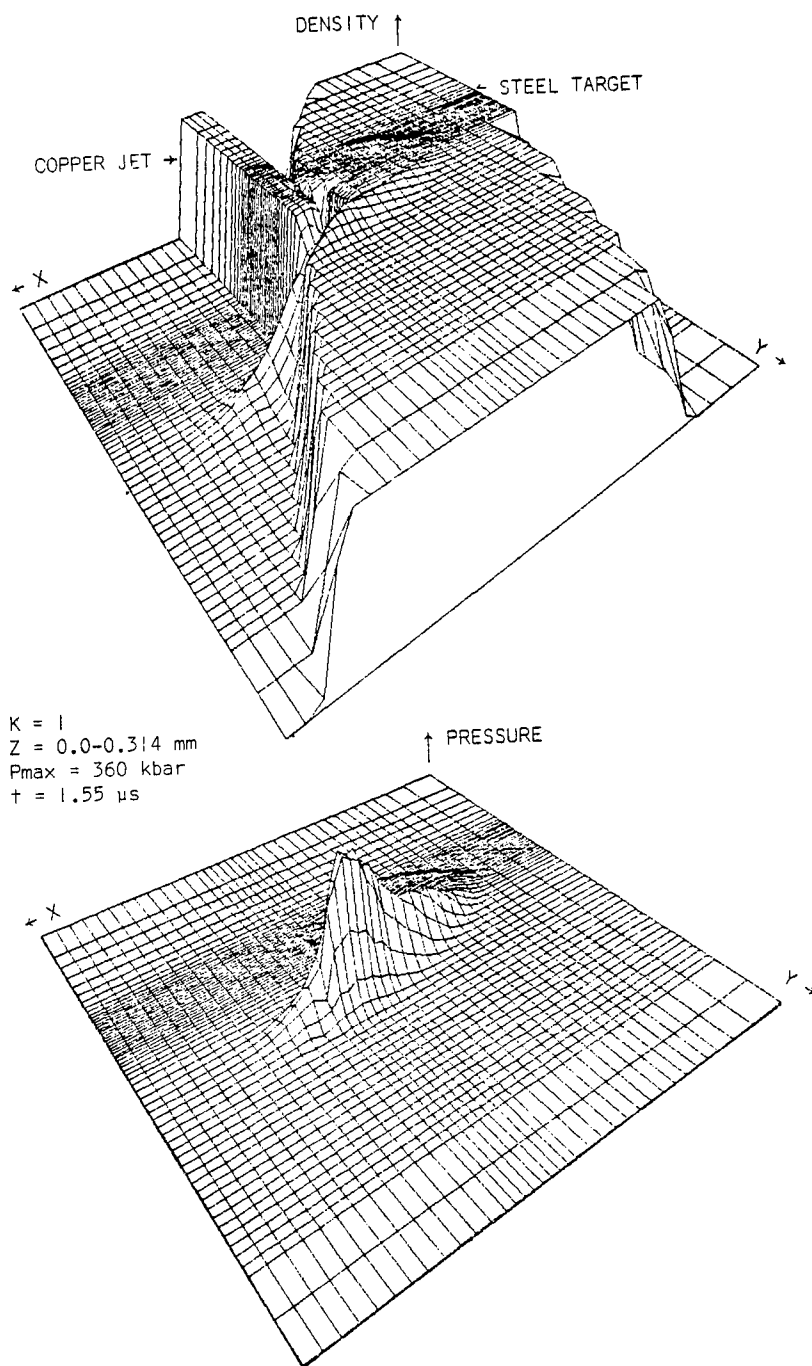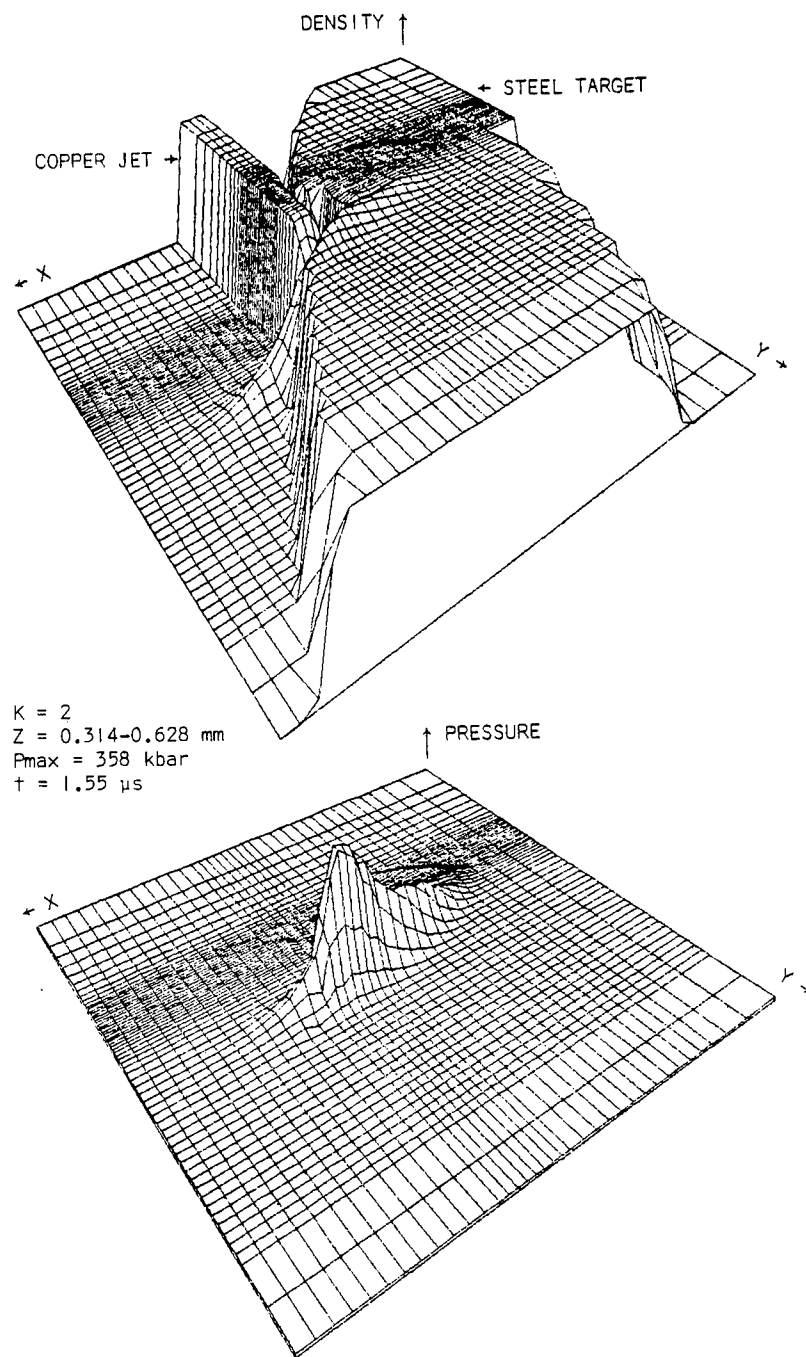Figure 3.   Penetrator-Target Configuration

DENSITY ↑

STEEL TARGET

COPPER JET →

X

Y

K = 1
Z = 0.0-0.314 mm
Pmax = 360 kbar
t = 1.55 μs

↑ PRESSURE

X

Y

Figure 4. Density and Pressure Fields

14

DENSITY ↑

← STEEL TARGET

COPPER JET →

← X

Y →

K = 2
Z = 0.314-0.628 mm
Pmax = 358 kbar
t = 1.55 μs

↑ PRESSURE

← X

Y →

Figure 5. Density and Pressure Fields

15

DENSITY ↑

← STEEL TARGET

← X

Y

K = 3
Z = 0.628-0.942 mm
Pmax = 286 kbar
t = 1.55 μs

↑ PRESSURE

← X

Y
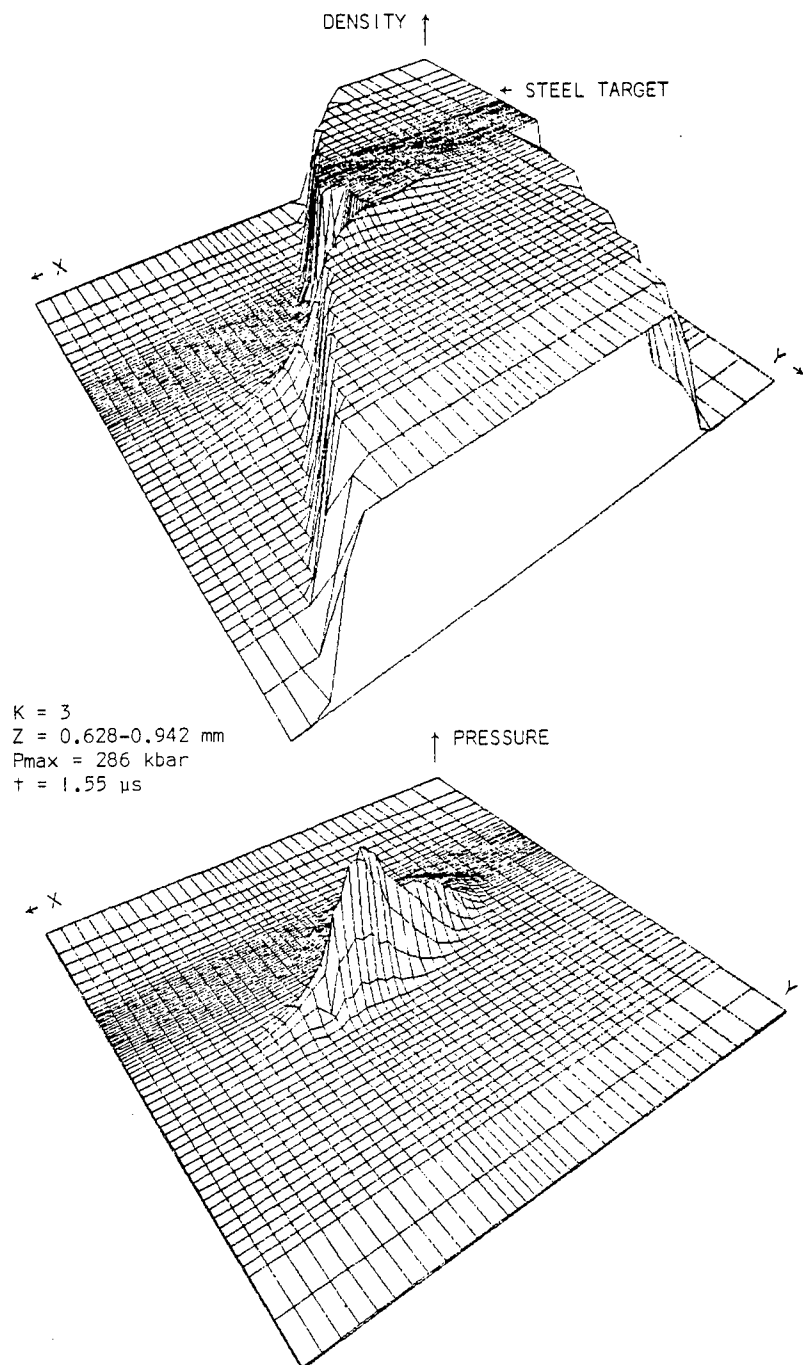
Figure 6. Density and Pressure Fields

16

DENSITY ↑

← STEEL TARGET

← X

Y

K = 4
Z = 0.942-1.256 mm
Pmax = 263 kbar
t = 1.55 μs

↑ PRESSURE

← X

Y
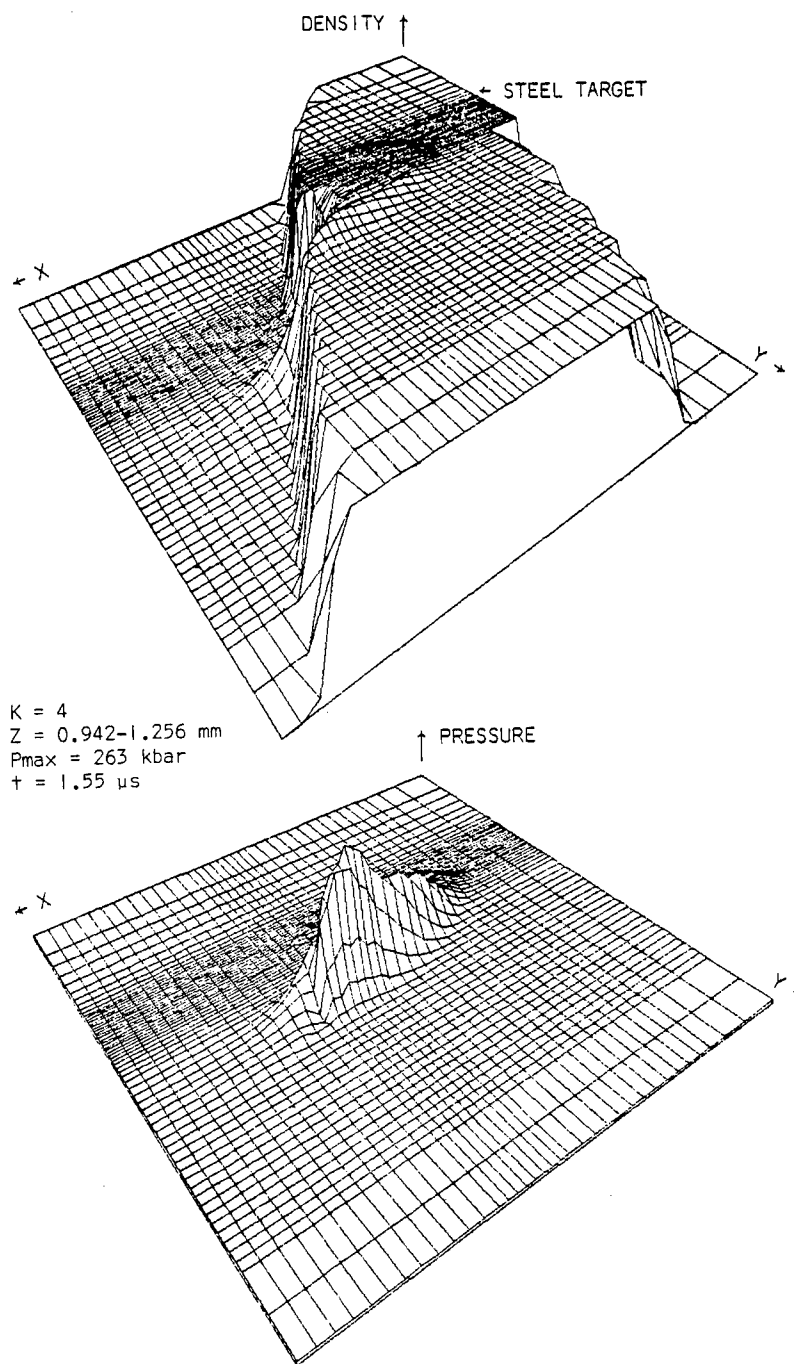
Figure 7.   Density and Pressure Fields

17

DENSITY ↑

← STEEL TARGET

← X

Y

K = 5
Z = 1.256-1.601 mm
Pmax = 218 kbar
t = 1.55 µs

↑ PRESSURE

← X

Y
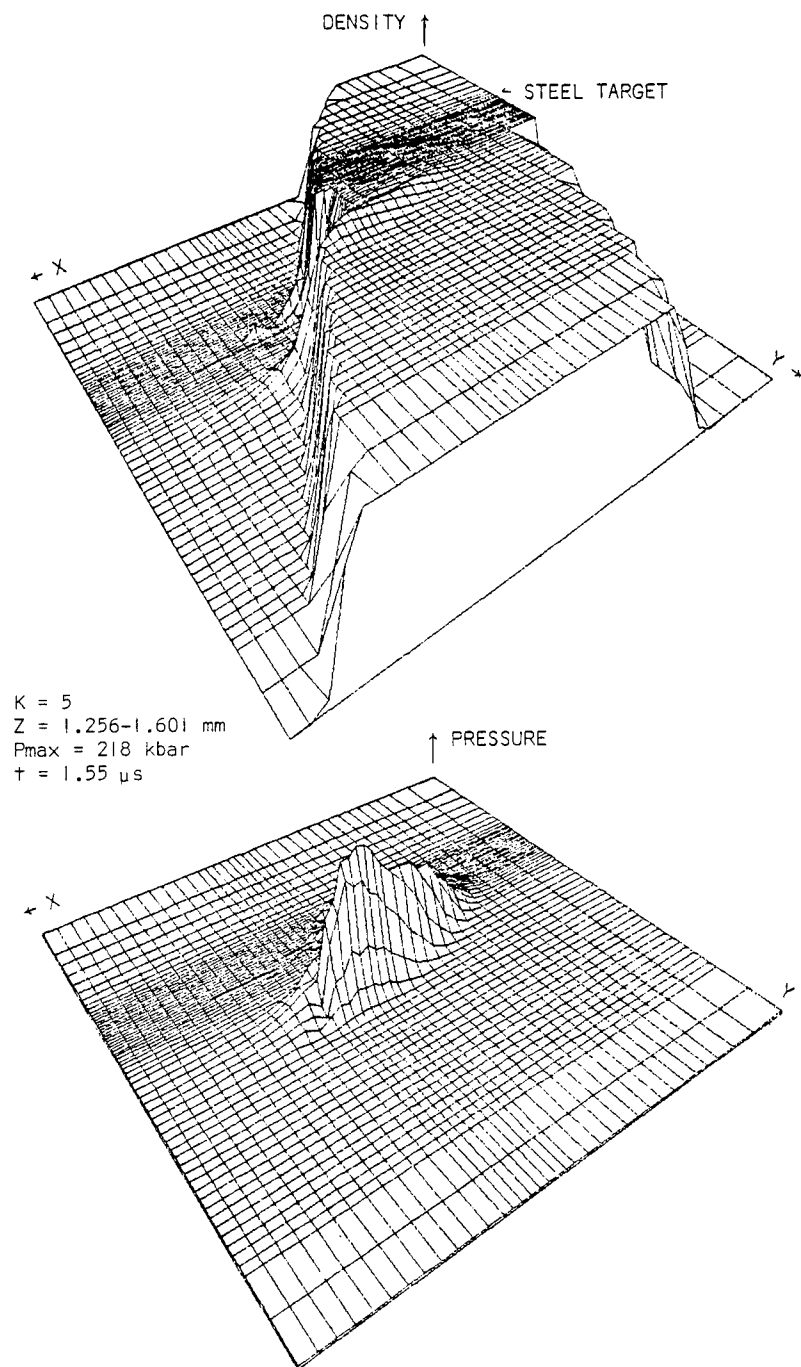
Figure 8.   Density and Pressure Fields

18

DENSITY ↑

← STEEL TARGET

← X

Y

K = 6
Z = 1.601-1.981 mm
Pmax = 175 kbar
t = 1.55 μs

↑ PRESSURE

← X

Y
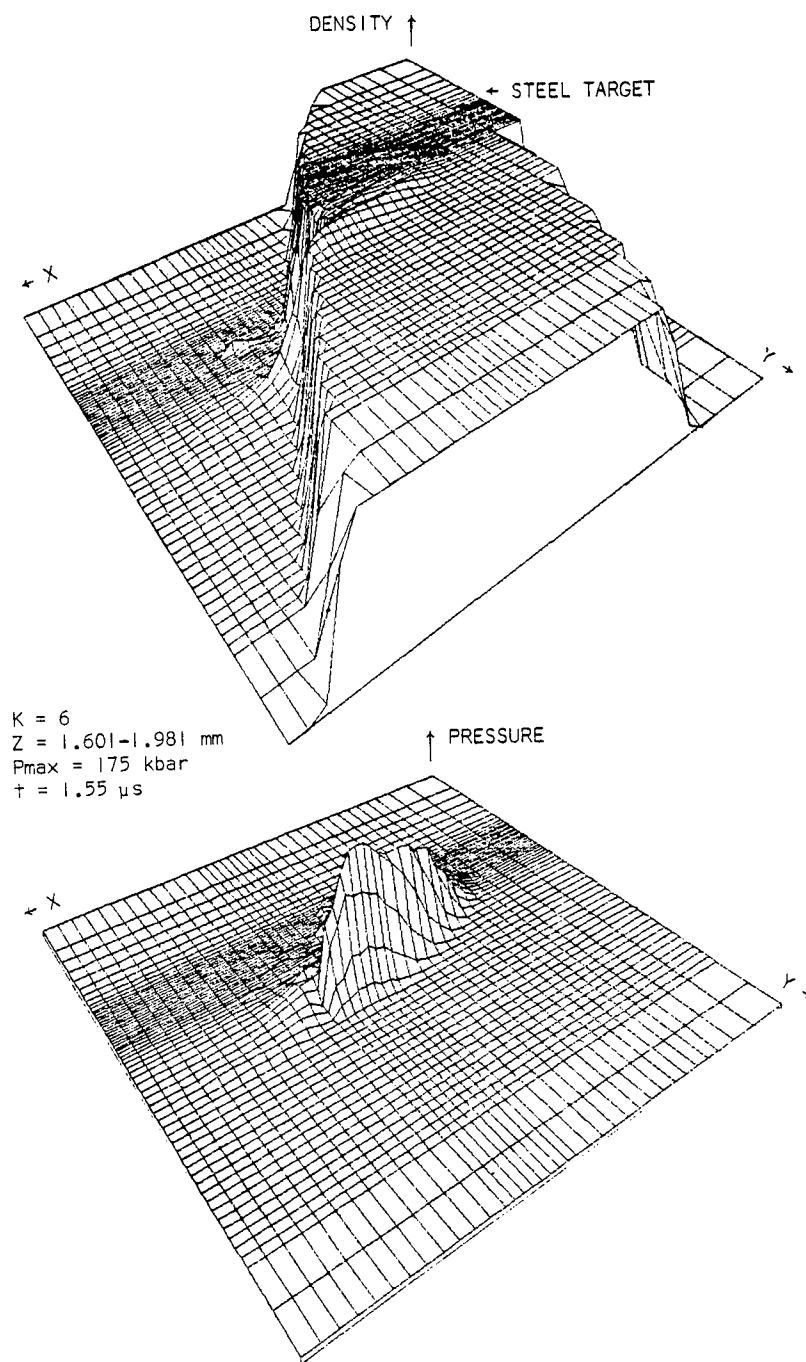
Figure 9. Density and Pressure Fields

19

DENSITY ↑

← STEEL TARGET

← X

Y →

K = 7
Z = 1.981-2.399 mm
Pmax = 139 kbar
t = 1.55 μs

↑ PRESSURE

← X

Y →
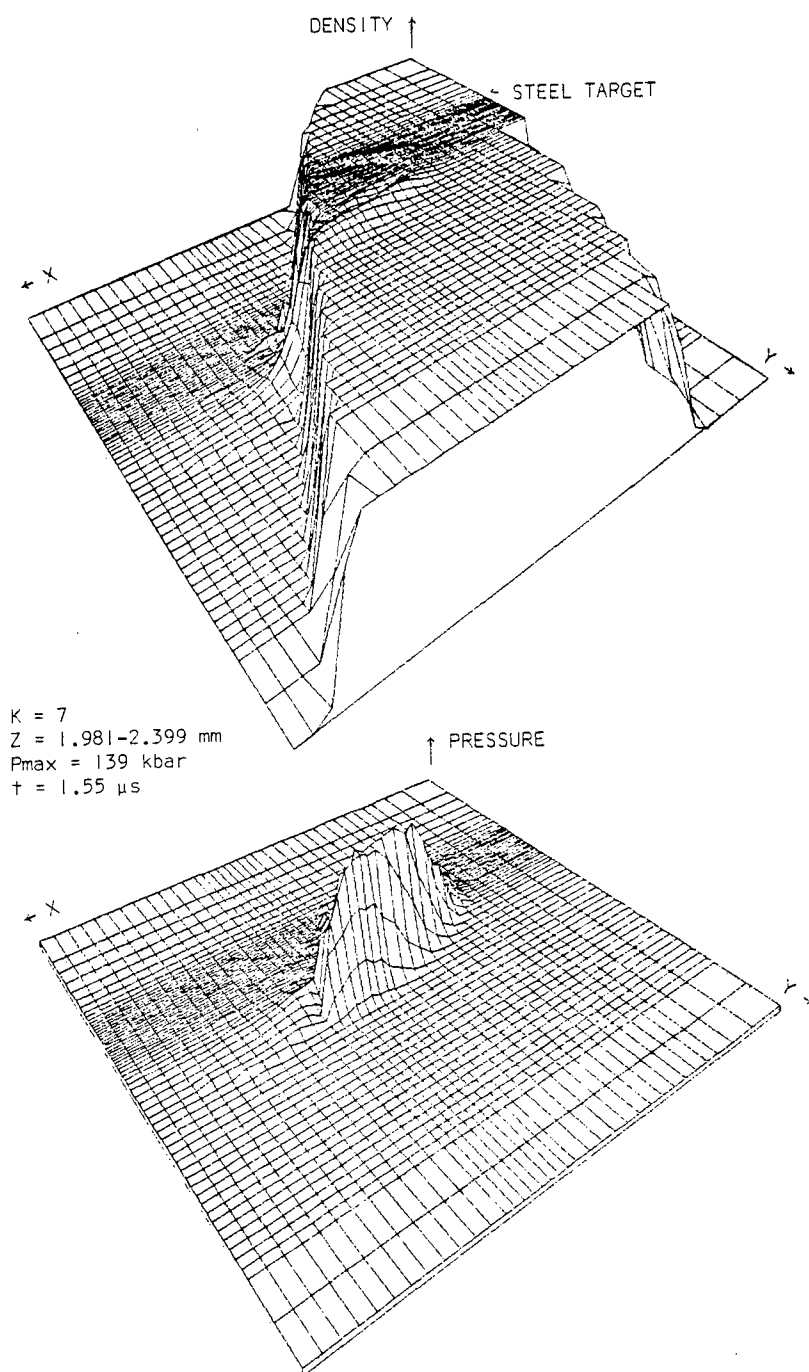
Figure 10. Density and Pressure Fields

20

DENSITY ↑

← STEEL TARGET

← X

Y →

K = 8
Z = 2.399-2.859 mm
Pmax = 135 kbar
t = 1.55 μs

↑ PRESSURE

← X

Y →
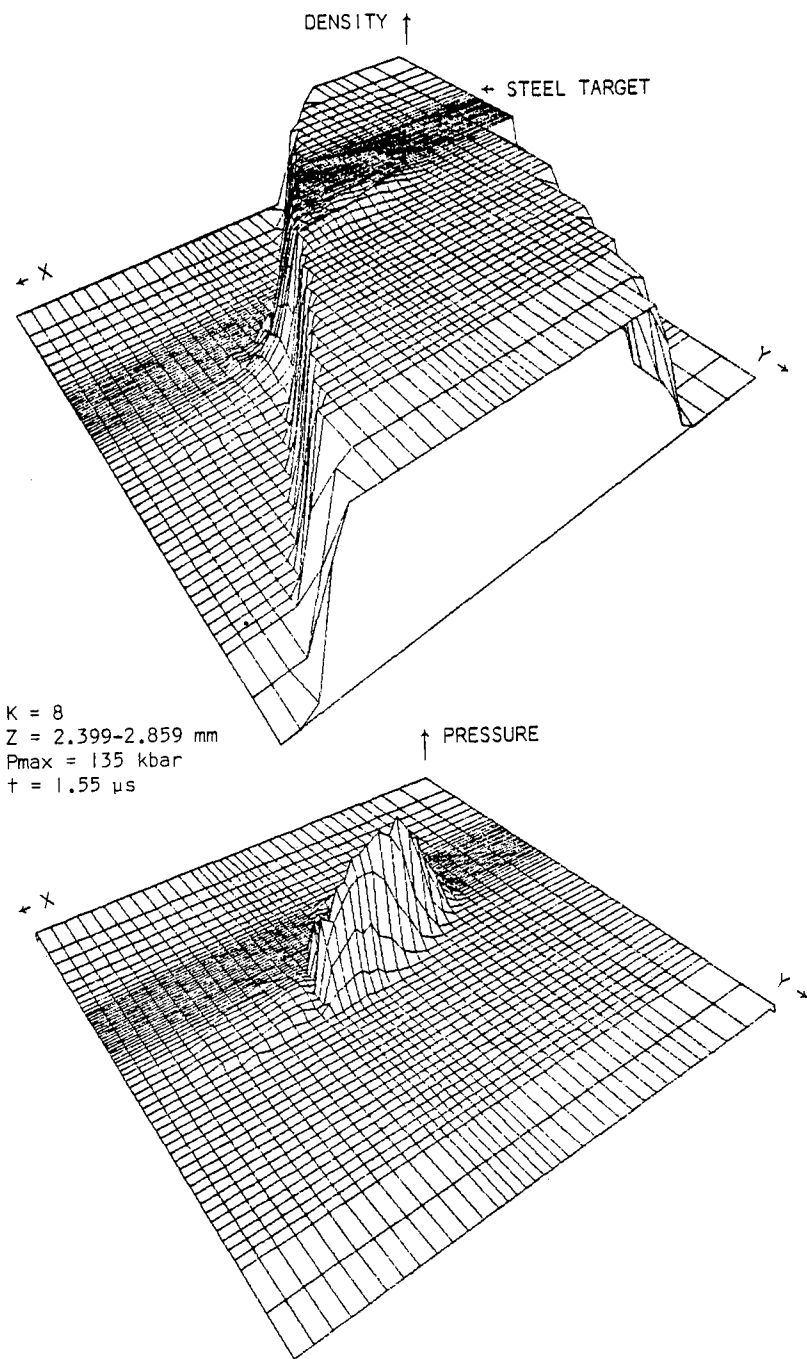
Figure 11. Density and Pressure Fields

21

DENSITY ↑

← STEEL TARGET

← X

→ Y

K = 9
Z = 2.859-3.365 mm
Pmax = 128 kbar
t = 1.55 μs

↑ PRESSURE

← X

→ Y
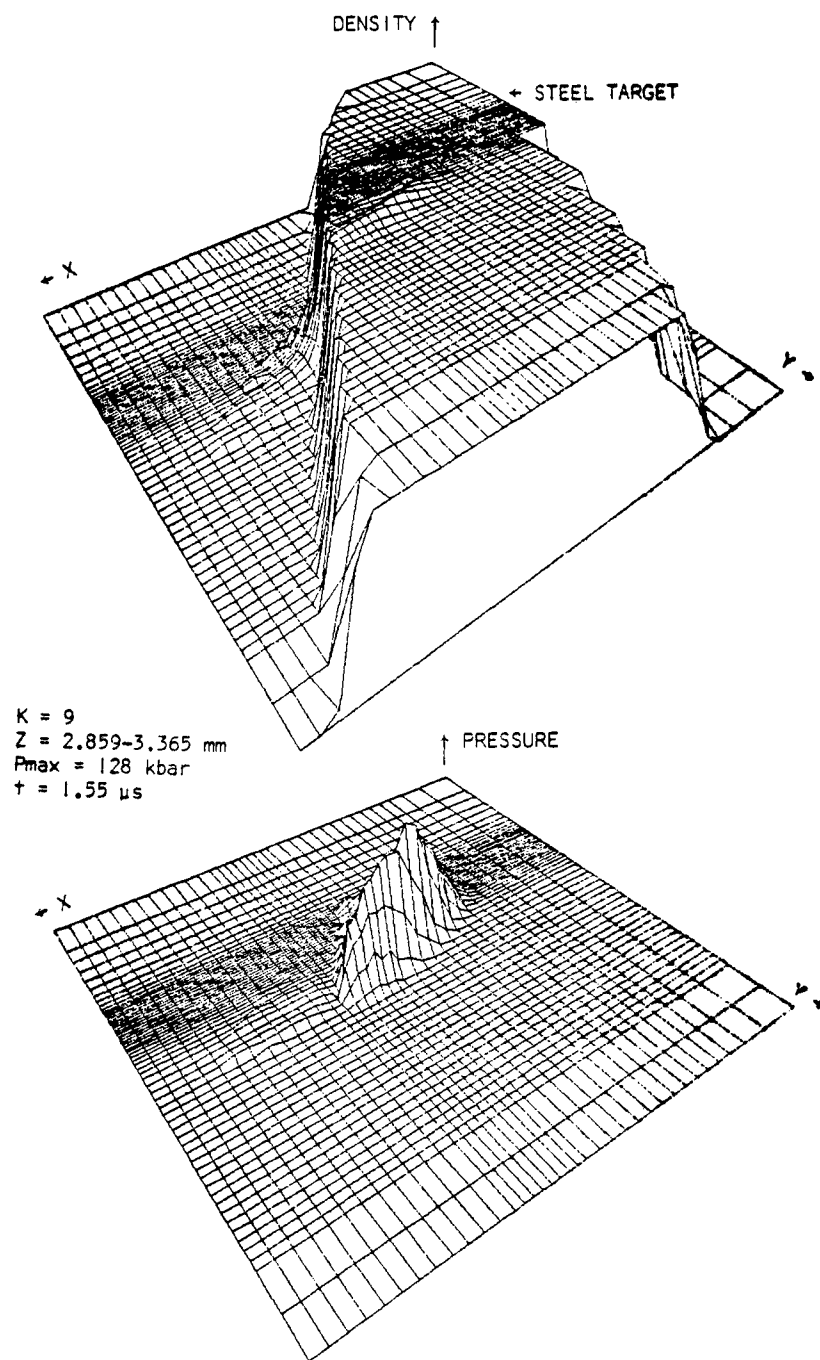
Figure 12.   Density and Pressure **Fields**

22

DENSITY ↑

← STEEL TARGET

← X

Y

K = 10
Z = 3.365-3.921 mm
Pmax = 101 kbar
t = 1.55 µs

↑ PRESSURE

← X

Y
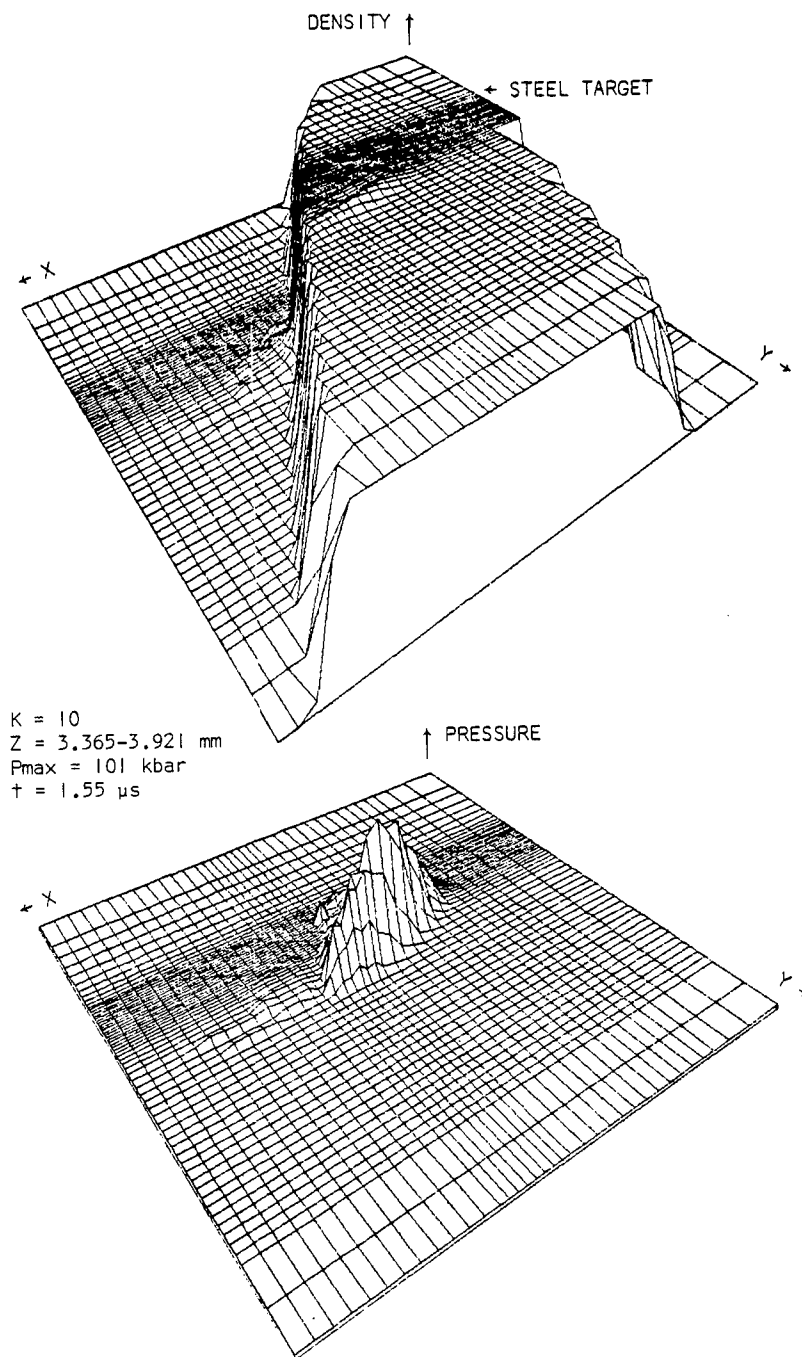
Figure 13. Density and Pressure Fields

23

DENSITY ↑

STEEL TARGET

← X

Y

K = ll
Z = 3.921−4.540 mm
Pmax = 6l kbar
t = l.55 μs

↑ PRESSURE

← X

Y
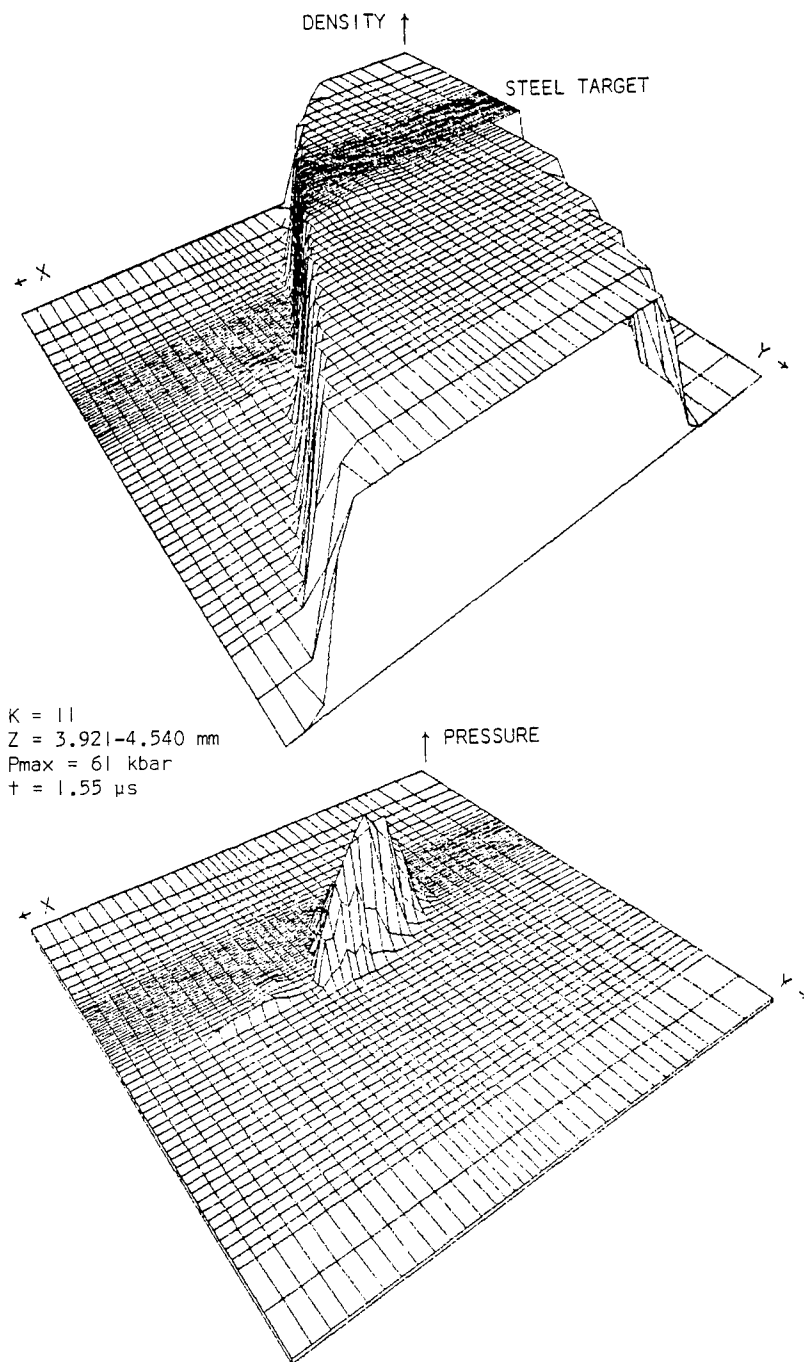
Figure 14. Density and Pressure Fields

24

DENSITY ↑

← STEEL TARGET

← X

Y →

K = 12
Z = 4.540-5.213 mm
Pmax = 34 kbar
t = 1.55 µs

↑ PRESSURE

← X

Y →
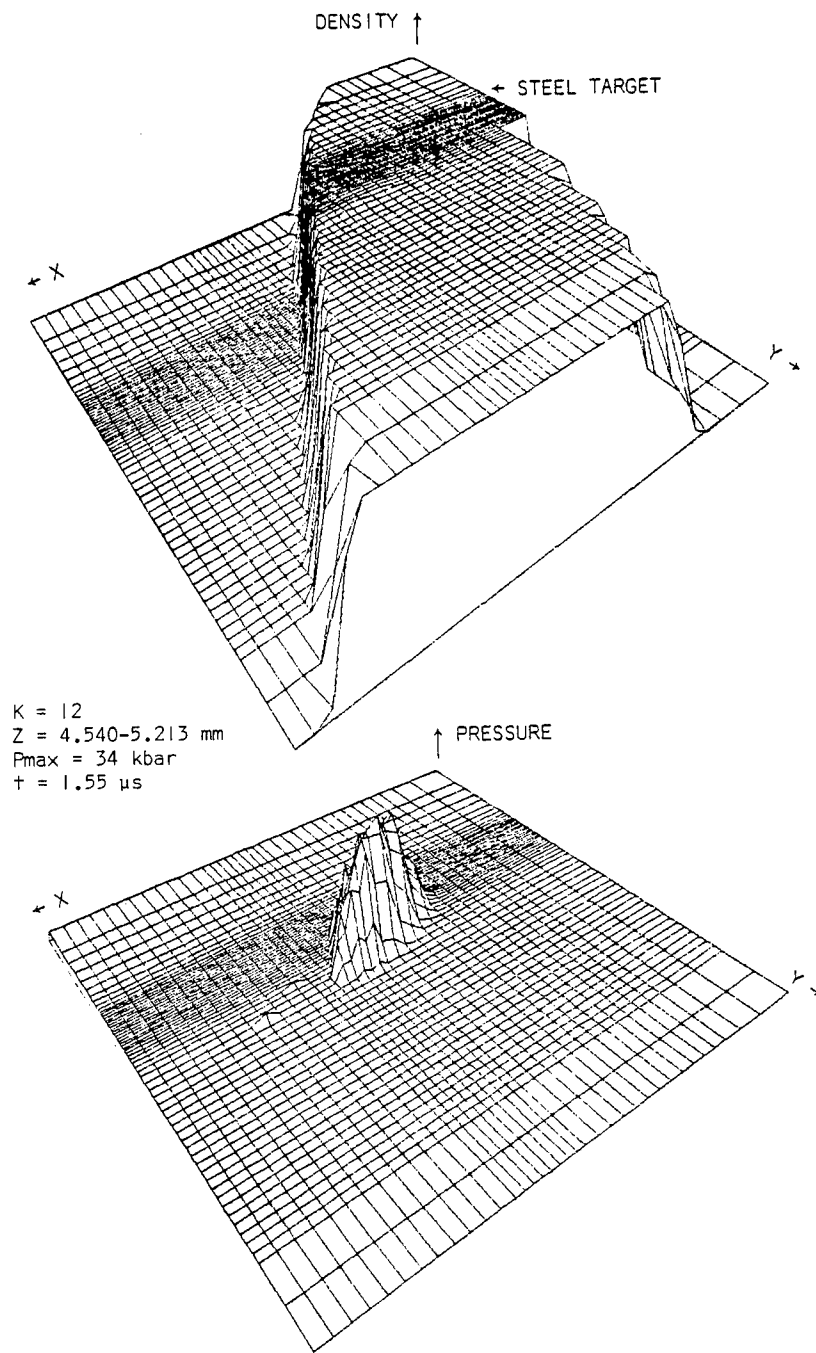
Figure 15. Density and Pressure Fields

25

DENSITY ↑

← STEEL TARGET

← X

Y →

K = 13
Z = 5.213-5.953 mm
Pmax = 17 kbar
t = 1.55 μs

↑ PRESSURE

← X

Y →
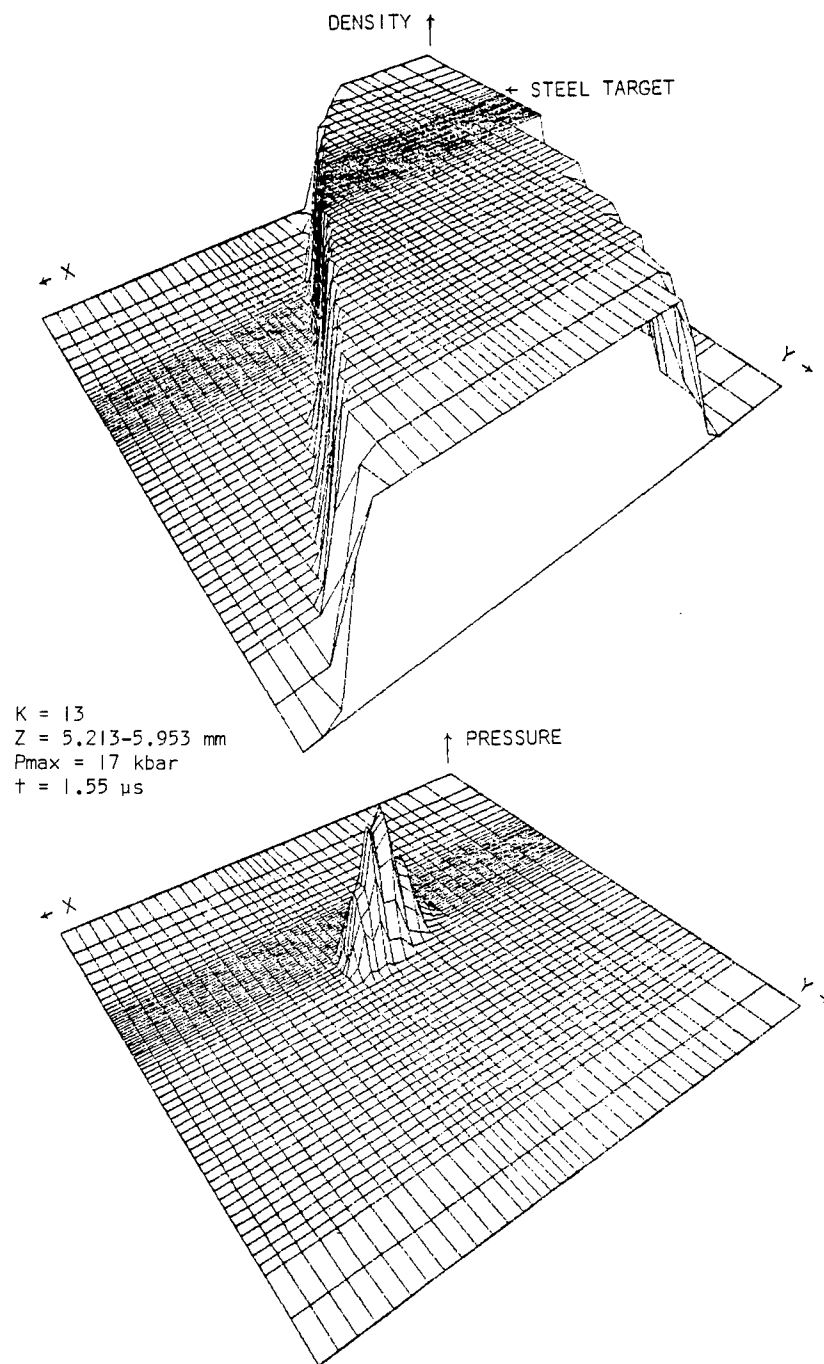
Figure 16. Density and Pressure Fields

26

DENSITY ↑

← STEEL TARGET

← X

Y ↘

K = 14
Z = 5.953-6.767 mm
Pmax = 5 kbar
t = 1.55 µs

↑ PRESSURE

← X

Y ↘
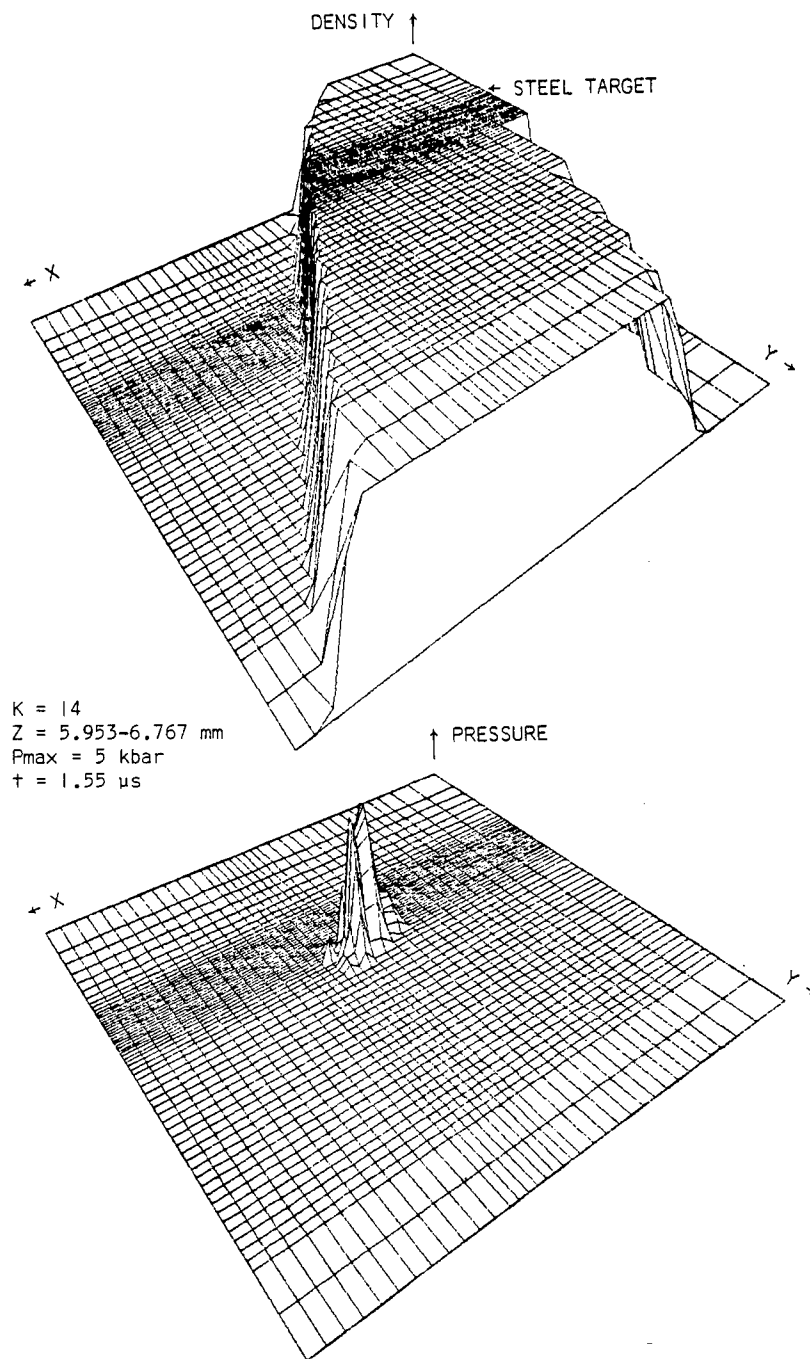
Figure 17.   Density and Pressure Fields

27

DENSITY ↑

← STEEL TARGET

← X

Y →

K = 15
Z = 6.767-8.367 mm
Pmax = 0.0 kbar
t = 1.55 µs

↑ PRESSURE

← X

Y →
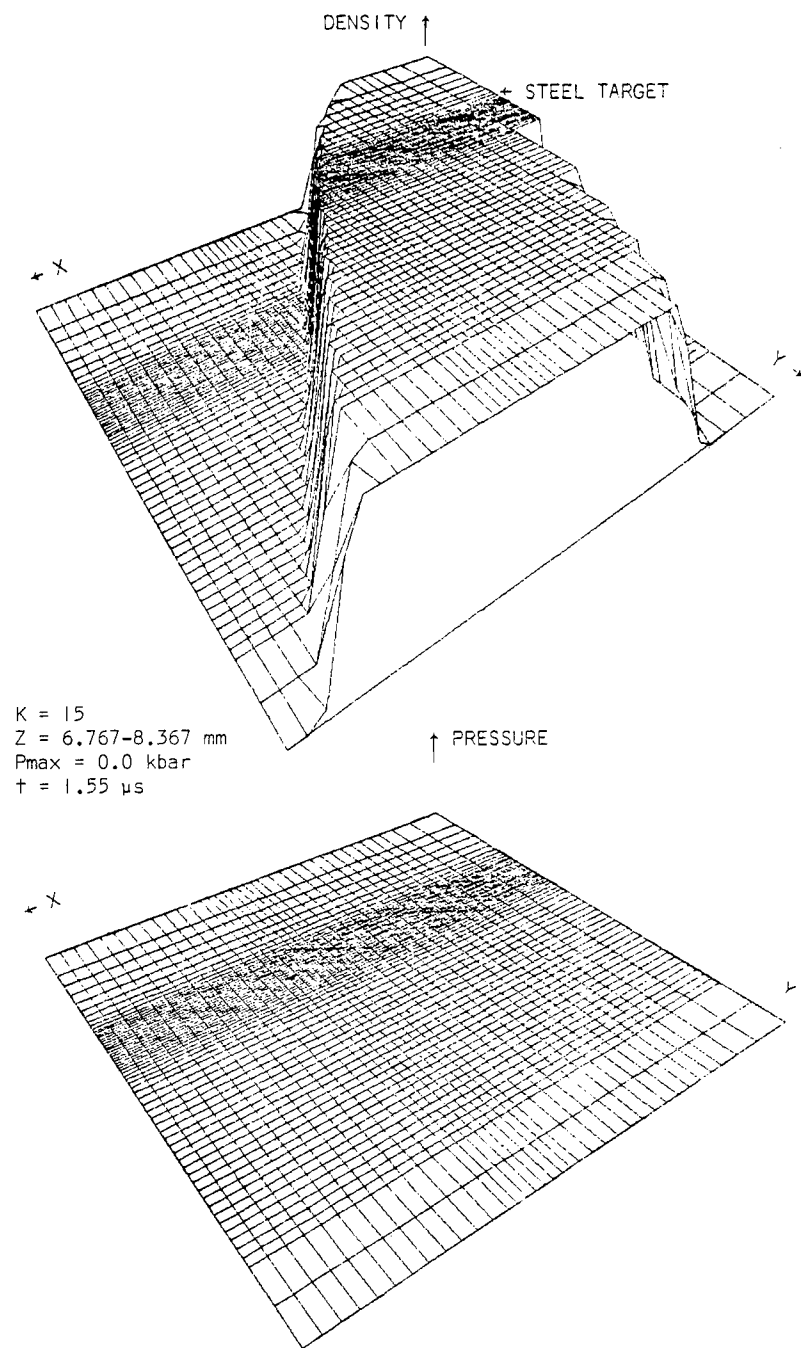
Figure 18. Density and Pressure Fields

28

DENSITY ↑

← STEEL TARGET

COPPER JET →

← X

Y →

K = 1
Z = 0.0-0.314 mm
Pmax = 388 kbar
t = 2.23 μs

↑ PRESSURE

← X

Y →
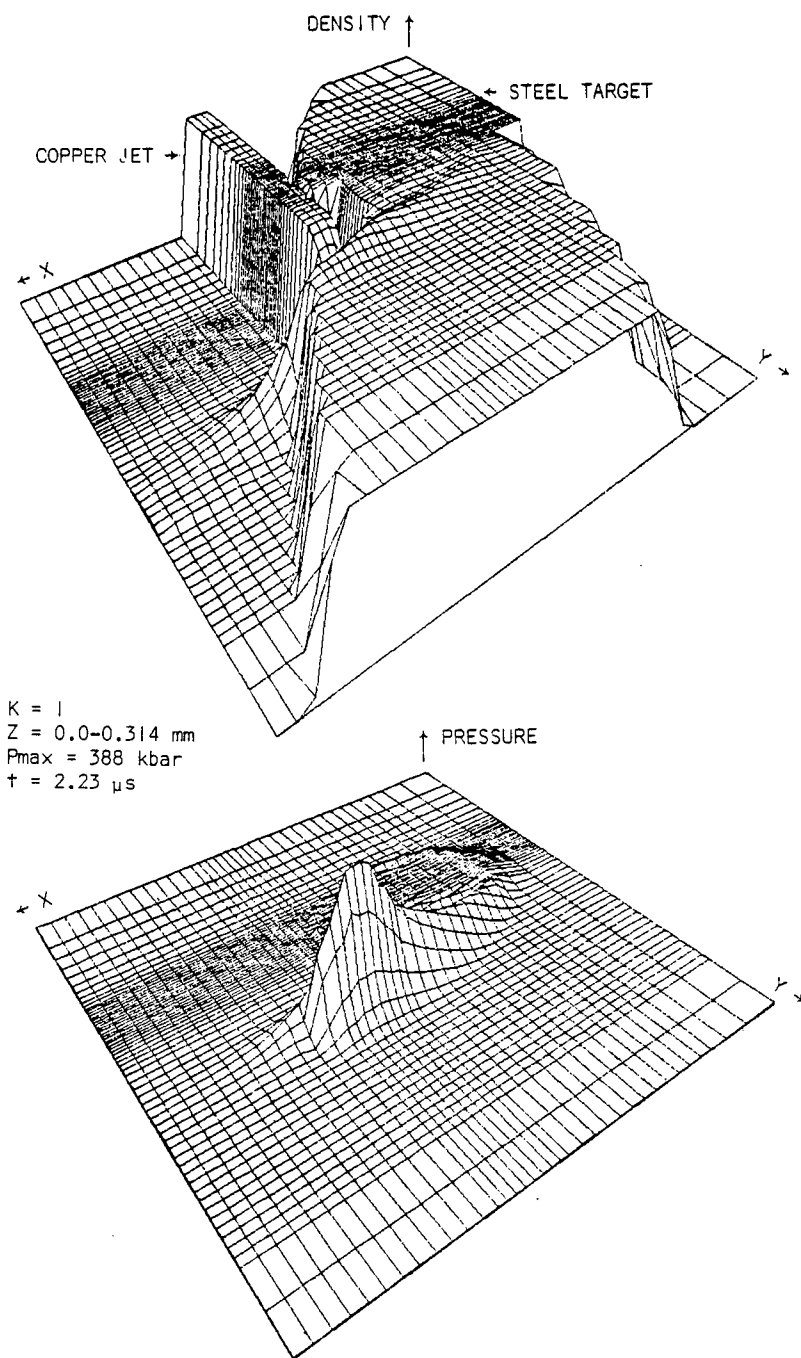
Figure 19. Density and Pressure Fields

29

DENSITY ↑

← STEEL TARGET

COPPER JET →

← X

Y

K = 2
Z = 0.314-0.628 mm
Pmax = 394 kbar
t = 2.23 μs

↑ PRESSURE

← X

Y

Figure 20. Density and Pressure Fields

30

DENSITY ↑

← STEEL TARGET

← X

Y →

K = 3
Z = 0.628-0.942 mm
Pmax = 320 kbar
t = 2.23 μs

↑ PRESSURE

← X

Y →

Figure 21. Density and Pressure Fields

31

DENSITY ↑

← STEEL TARGET

← X

Y

K = 4
Z = 0.942—1.256 mm
Pmax = 279 kbar
t = 2.23 μs

↑ PRESSURE

← X

Y
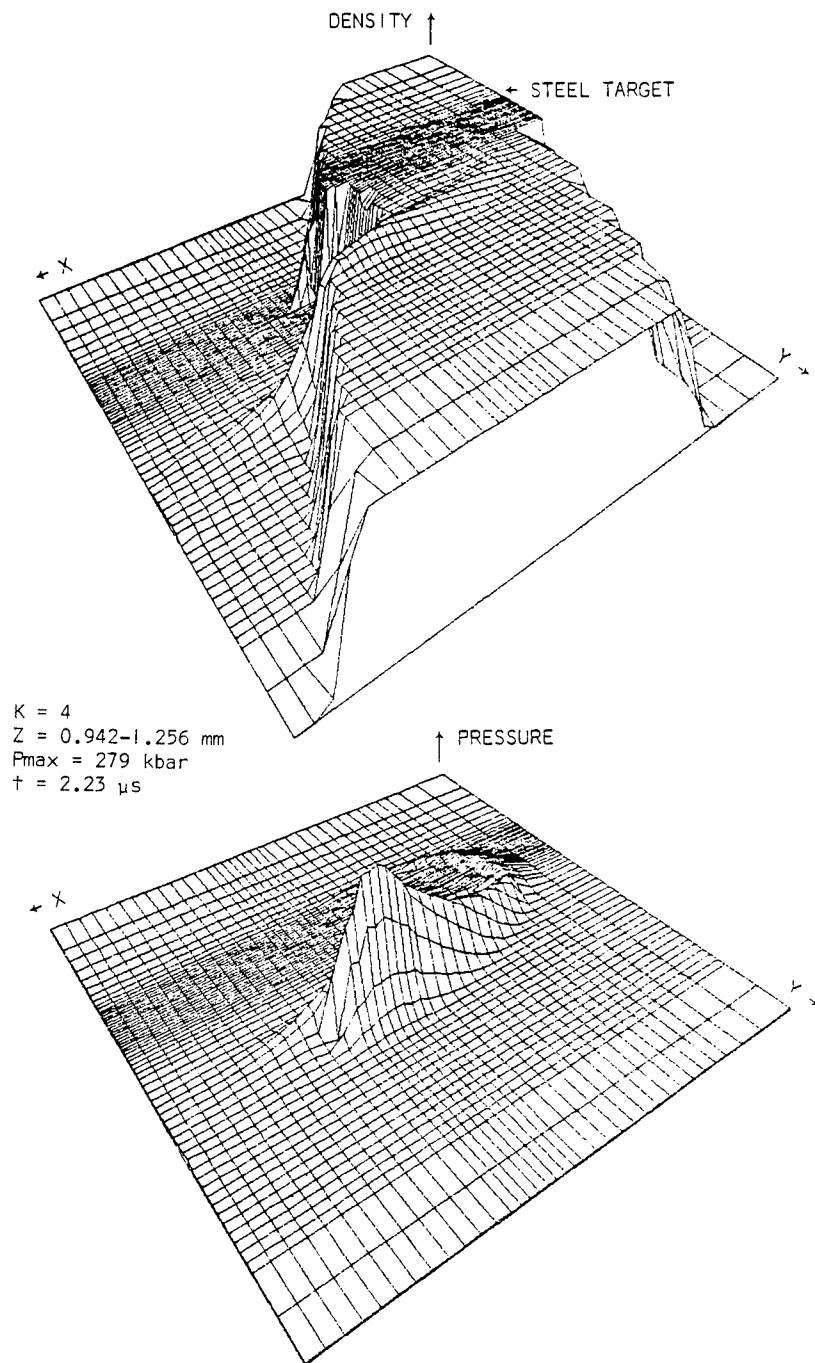
Figure 22. Density and Pressure Fields

32

DENSITY ↑

← STEEL TARGET

← X

Y →

K = 5
Z = 1.256−1.601 mm
Pmax = 228 kbar
t = 2.23 µs

↑ PRESSURE

← X

Y →
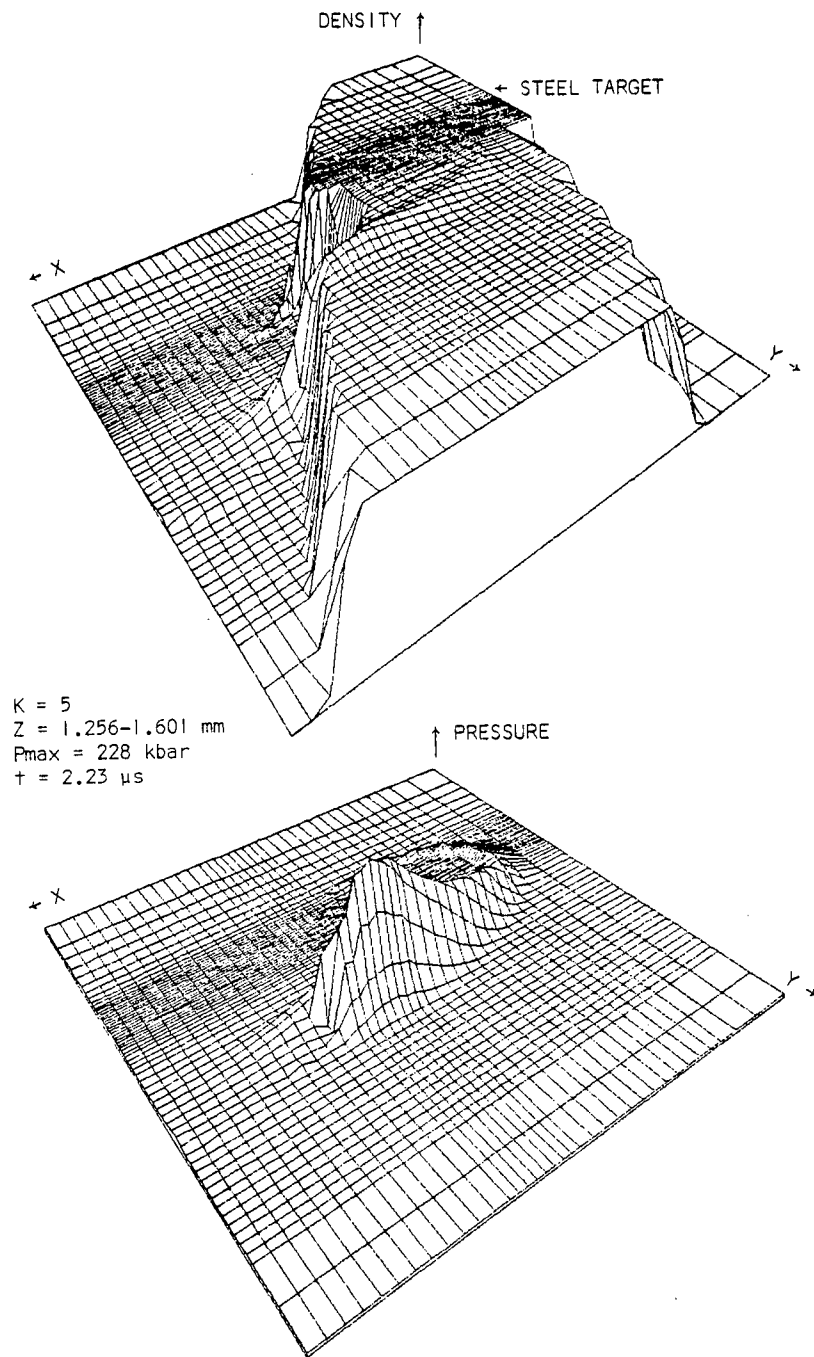
Figure 23. Density and Pressure Fields

33

DENSITY ↑

← STEEL TARGET

← X

Y

K = 6
Z = 1.601-1.981 mm
Pmax = 196 kbar
t = 2.23 μs

↑ PRESSURE

← X

Y
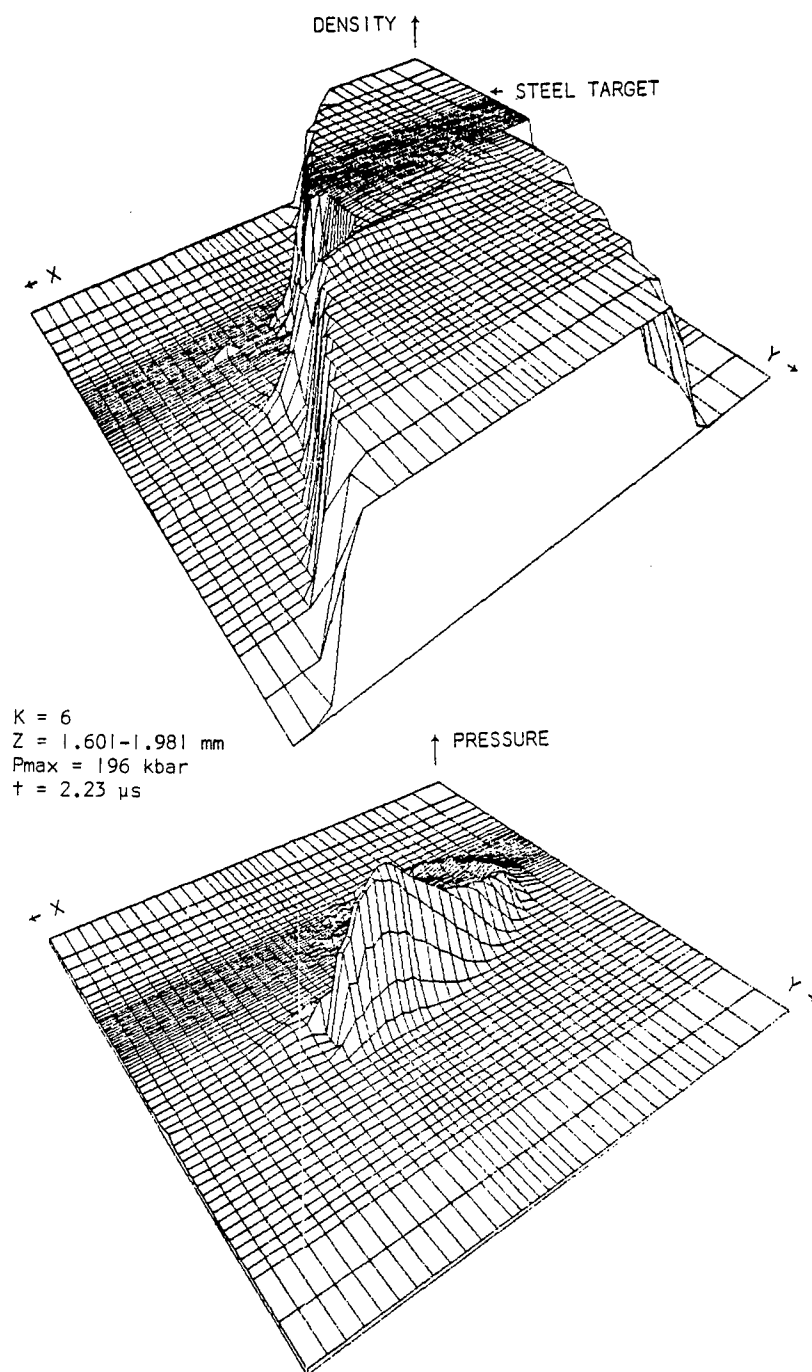
Figure 24. Density and Pressure Fields

34

DENSITY ↑

← STEEL TARGET

← X

Y →

K = 7
Z = 1.981−2.399 mm
Pmax = 170 kbar
t = 2.23 μs

↑ PRESSURE

← X

Y →
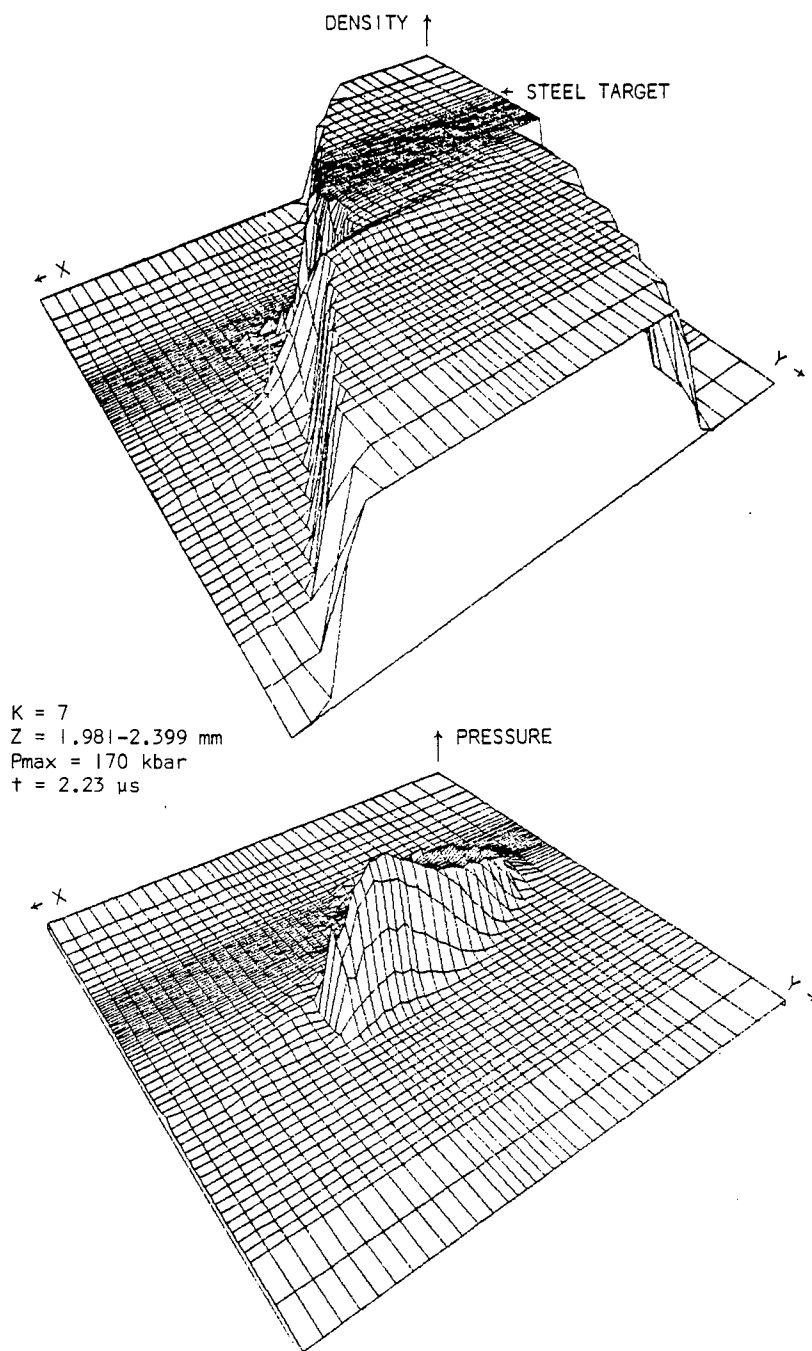
Figure 25. Density and Pressure Fields

35

DENSITY ↑

← STEEL TARGET

← X

Y

K = 8
Z = 2.399–2.859 mm
Pmax = 141 kbar
t = 2.23 μs

↑ PRESSURE

← X

Y
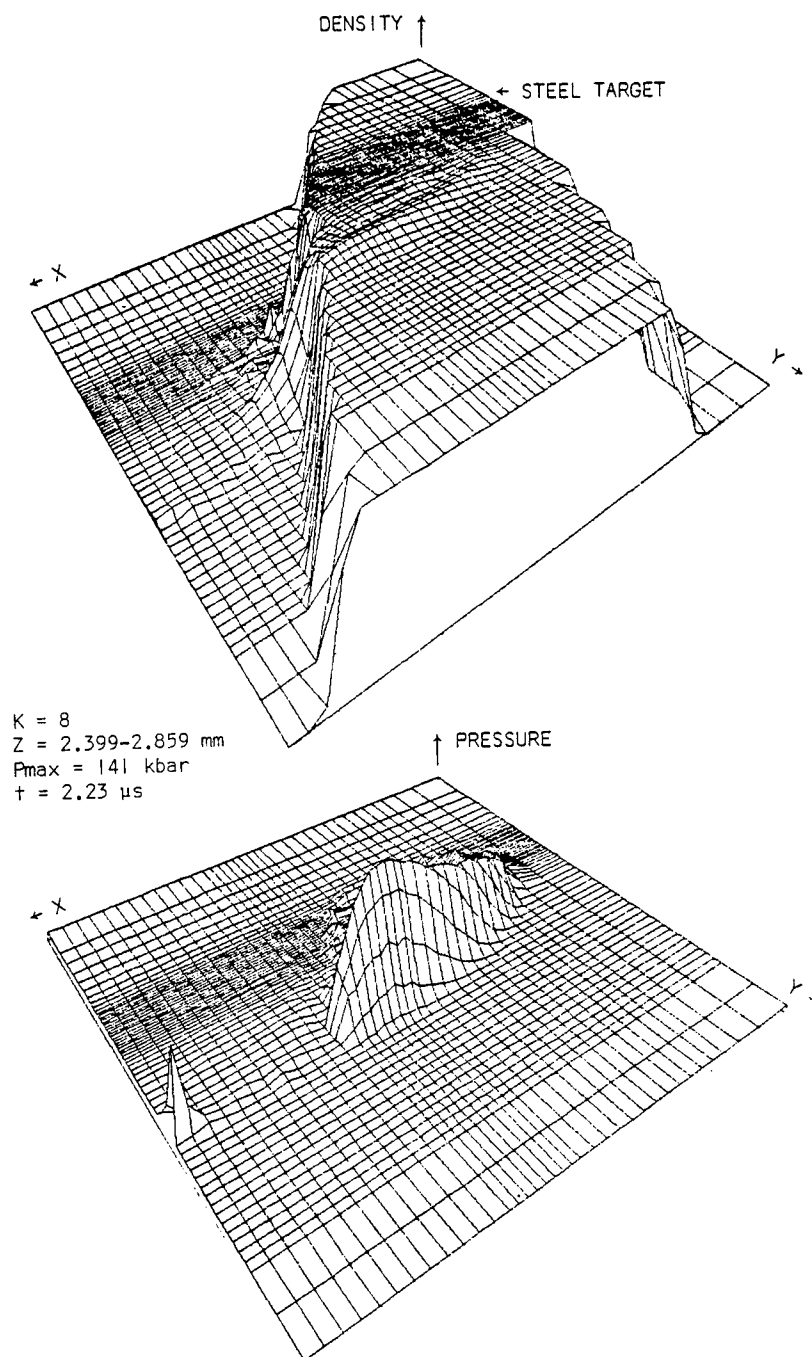
Figure 26.   Density and Pressure Fields

36

DENSITY ↑

← STEEL TARGET

← X

Y →

K = 9
Z = 2.859-3.365 mm
Pmax = 115 kbar
t = 2.23 μs

↑ PRESSURE

← X

Y →
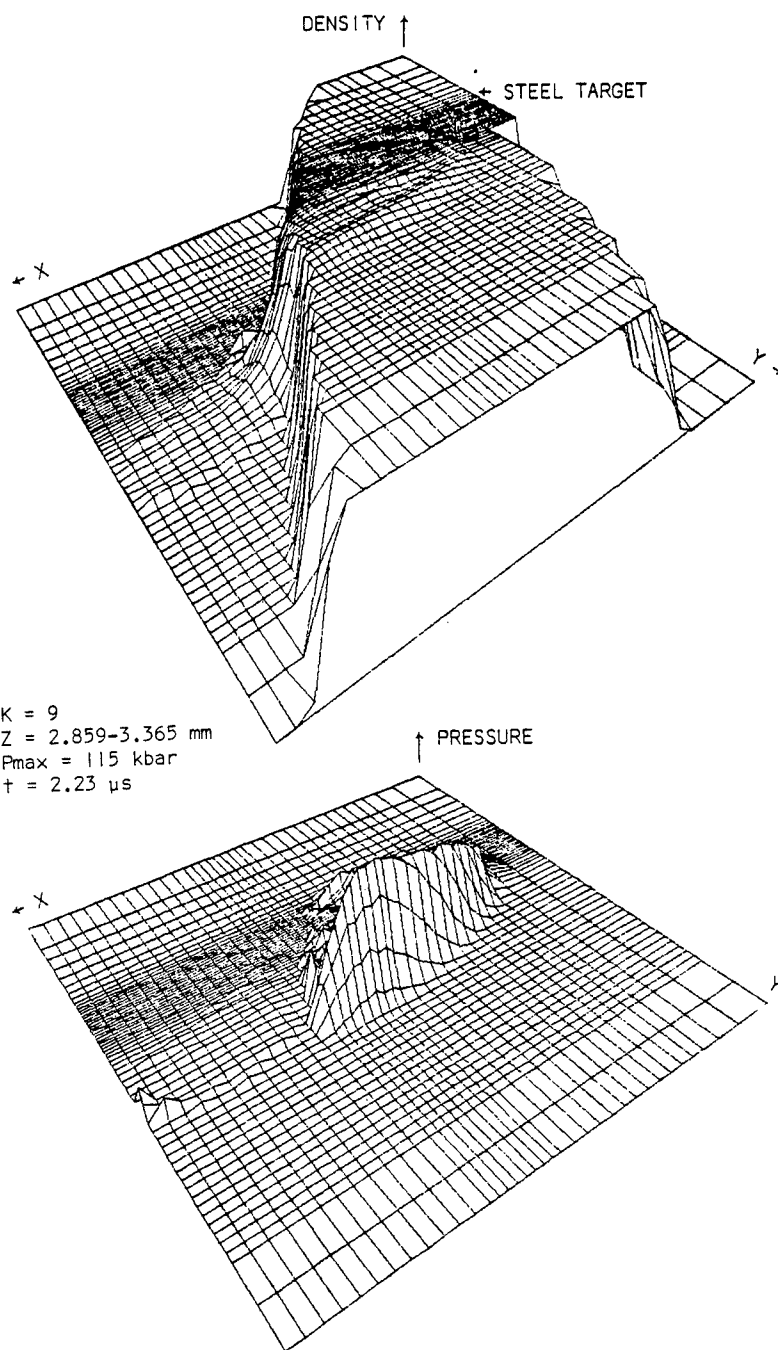
Figure 27. Density and Pressure Fields

37

DENSITY ↑

← STEEL TARGET

← X

Y →

K = 10
Z = 3.365-3.921 mm
Pmax = 96 kbar
t = 2.23 μs

↑ PRESSURE

← X

Y →
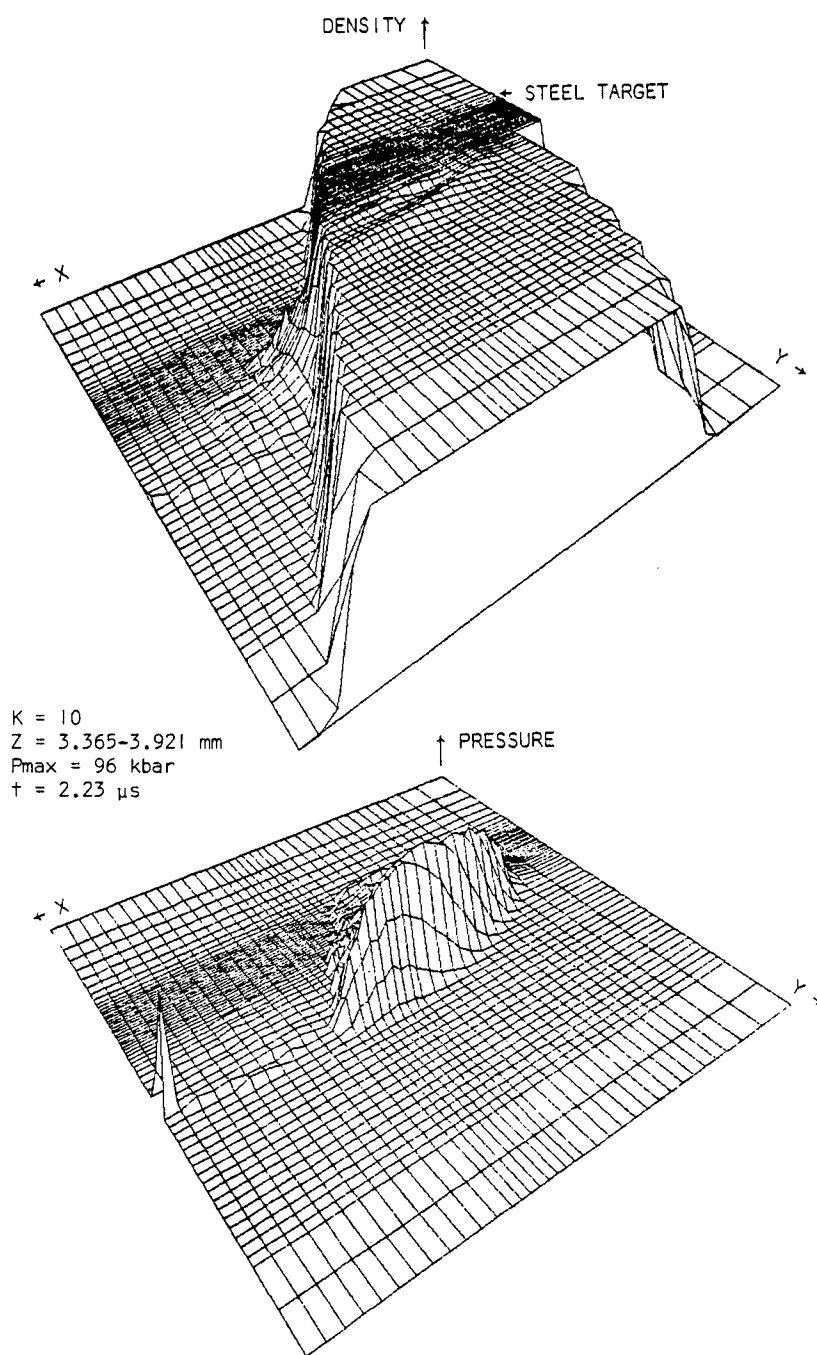
Figure 28. Density and Pressure Fields

38

DENSITY ↑

← STEEL TARGET

← X

↑ Y

K = 11
Z = 3.921-4.540 mm
Pmax = 86 kbar
t = 2.23 μs

↑ PRESSURE

← X

→ Y
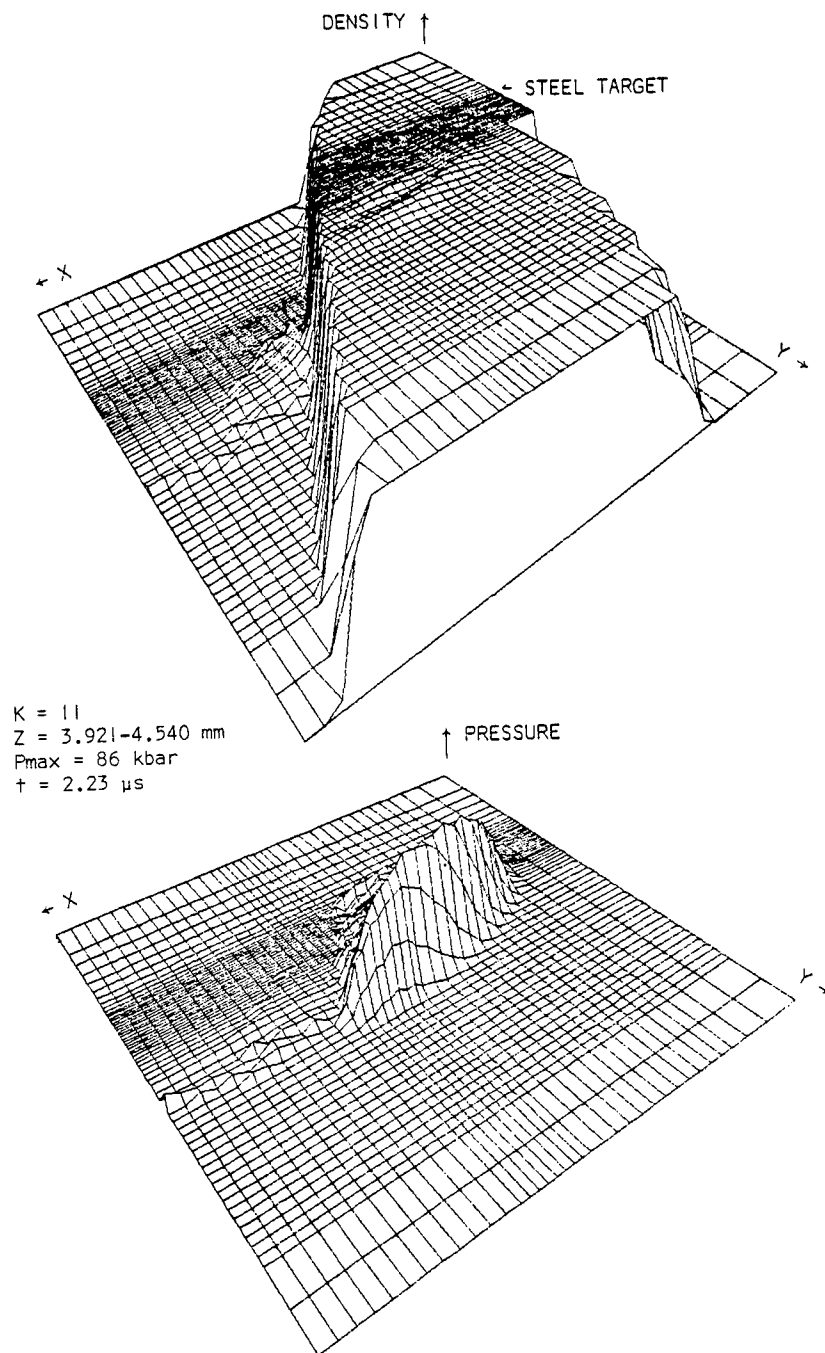
Figure 29. Density and Pressure Fields

39
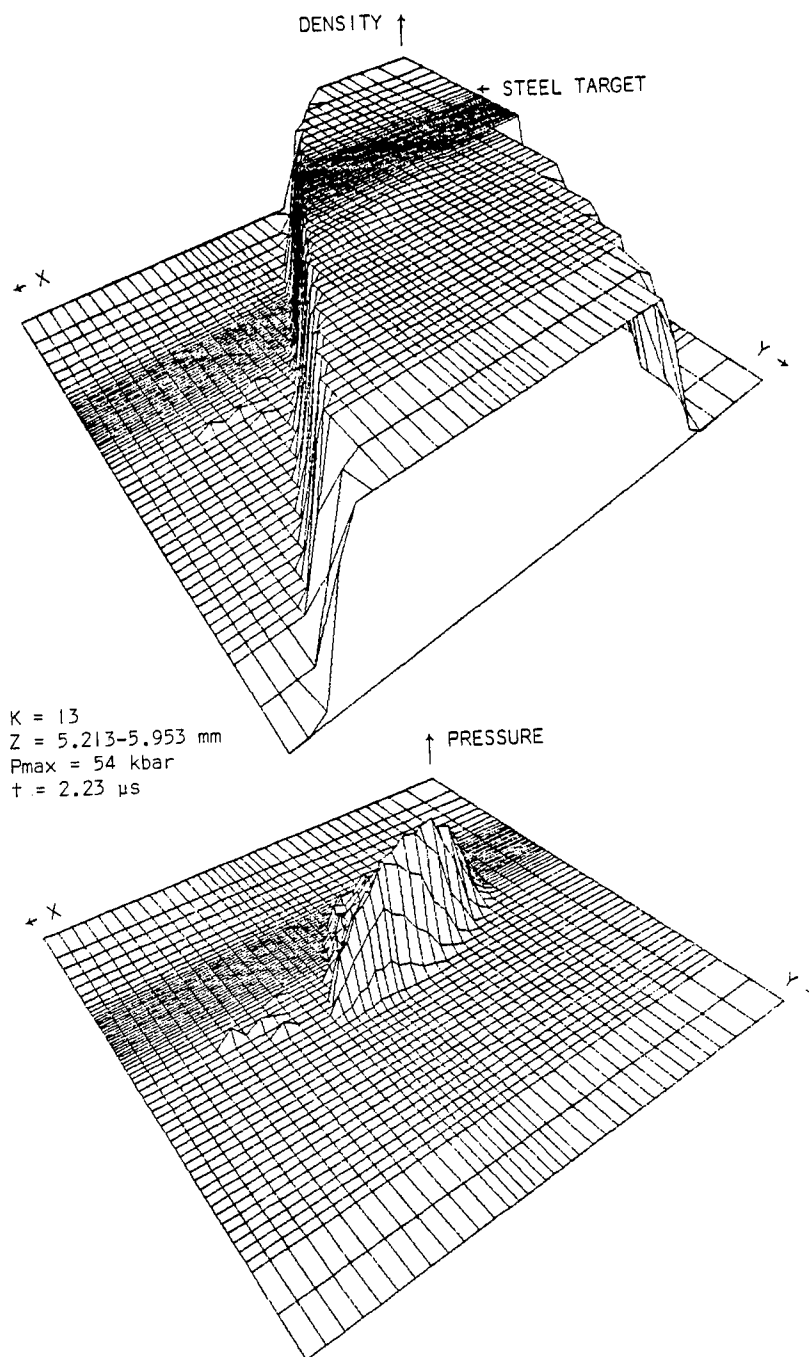
Figure 30. Density and Pressure Fields

40

DENSITY ↑

STEEL TARGET

X

Y

K = 14
Z = 5.953-6.767 mm
Pmax = 41 kbar
t = 2.23 μs

↑ PRESSURE

X

Y
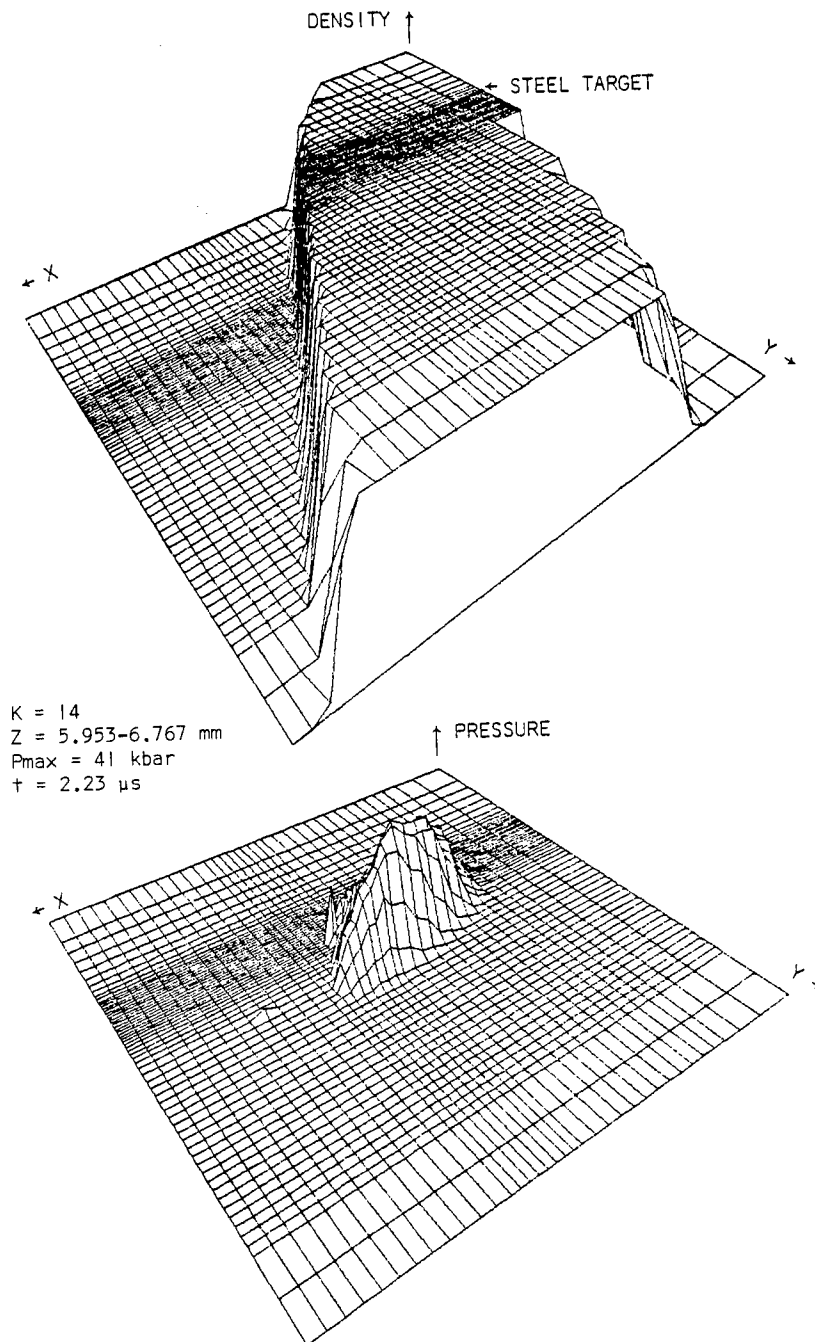
Figure 31. Density and Pressure Fields

41

DENSITY ↑

← STEEL TARGET

← X

Y

K = 15
Z = 6.767-8.367 mm
Pmax = 15 kbar
t = 2.23 μs

↑ PRESSURE

← X

Y
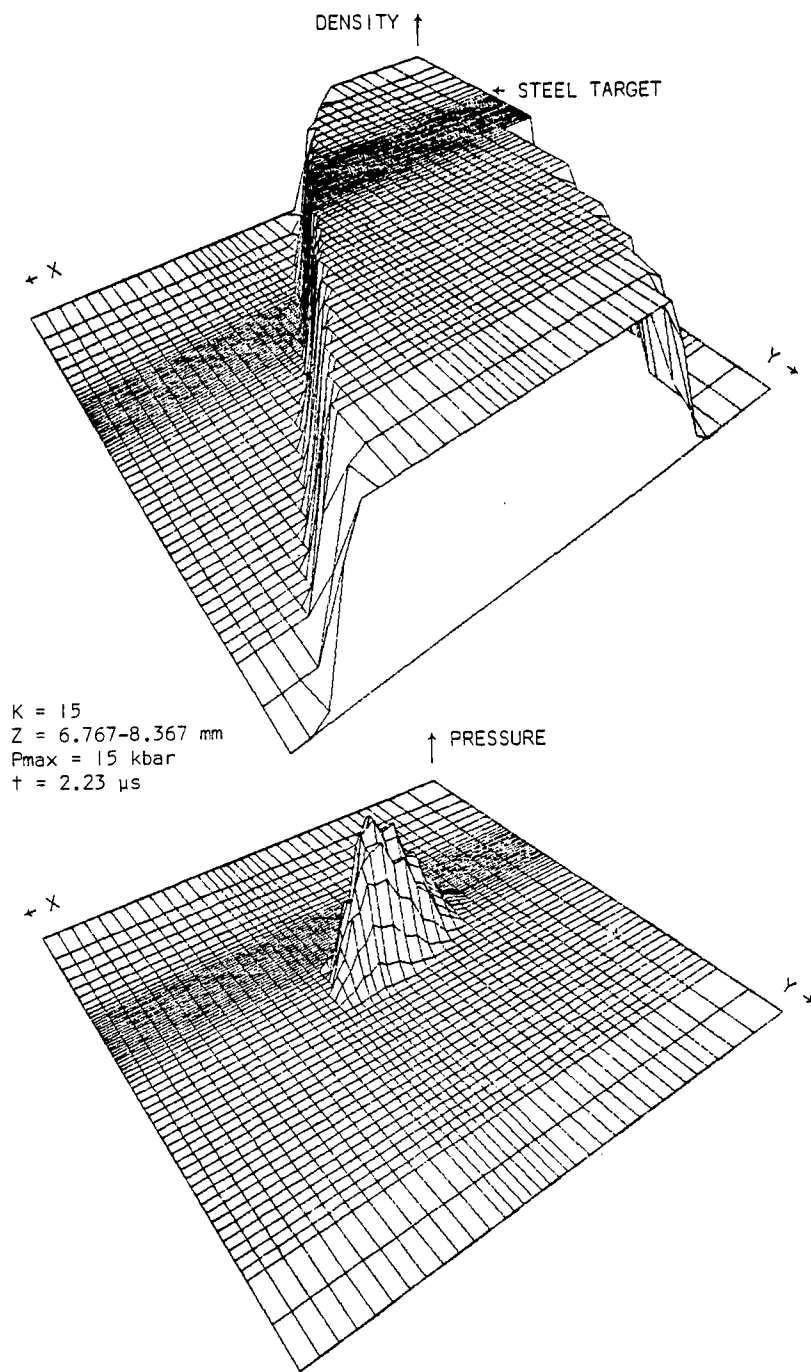
Figure 32.   Density and Pressure Fields

42

DENSITY ↑

COPPER JET →

STEEL TARGET ←

← X

Y →

K = 1
Z = 0.0-0.314 mm
Pmax = 406 kbar
t = 2.65 us

↑ PRESSURE

← X

Y →
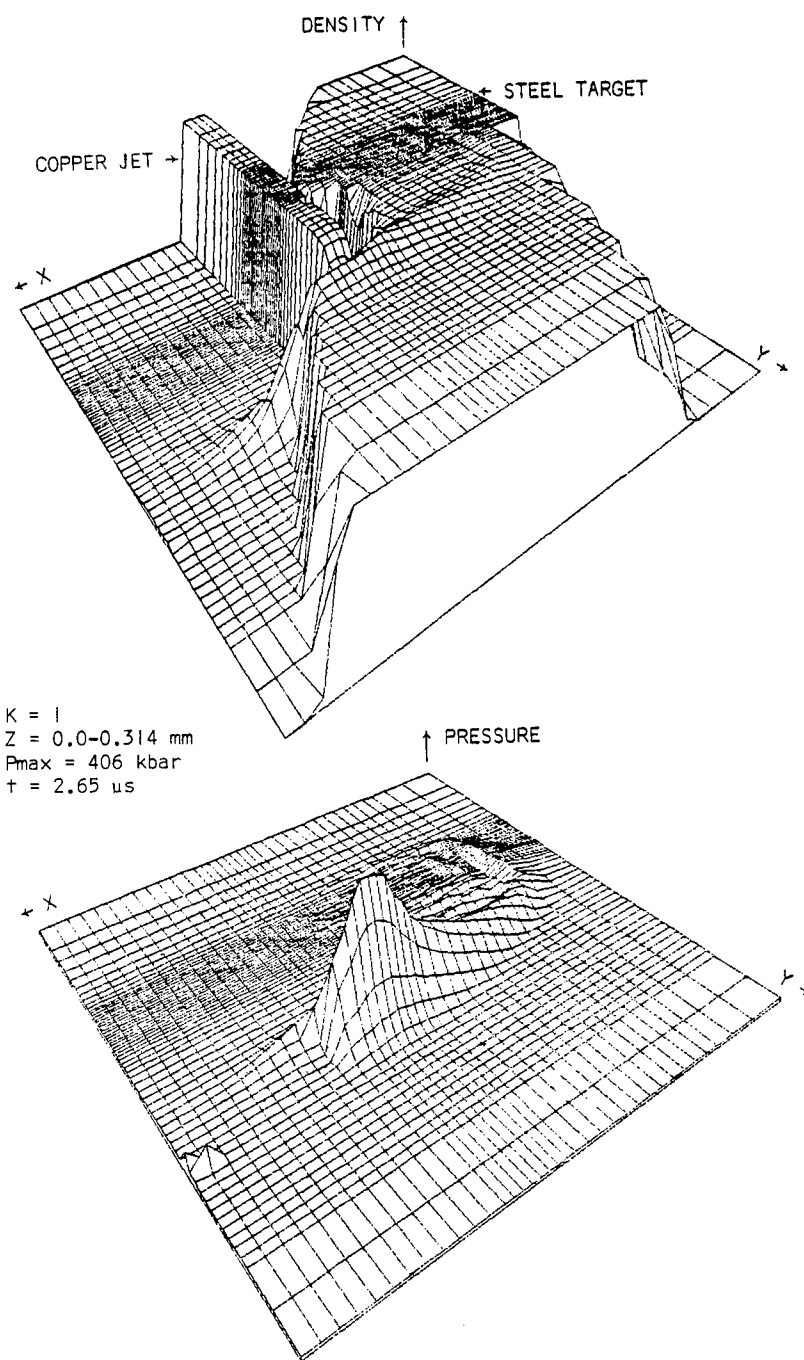
Figure 33. Density and Pressure Fields

43

DENSITY ↑

STEEL TARGET →

COPPER JET →

← X

Y →

K = 2
Z = 0.314–0.628 mm
Pmax = 404 kbar
t = 2.65 μs

↑ PRESSURE

← X

Y →
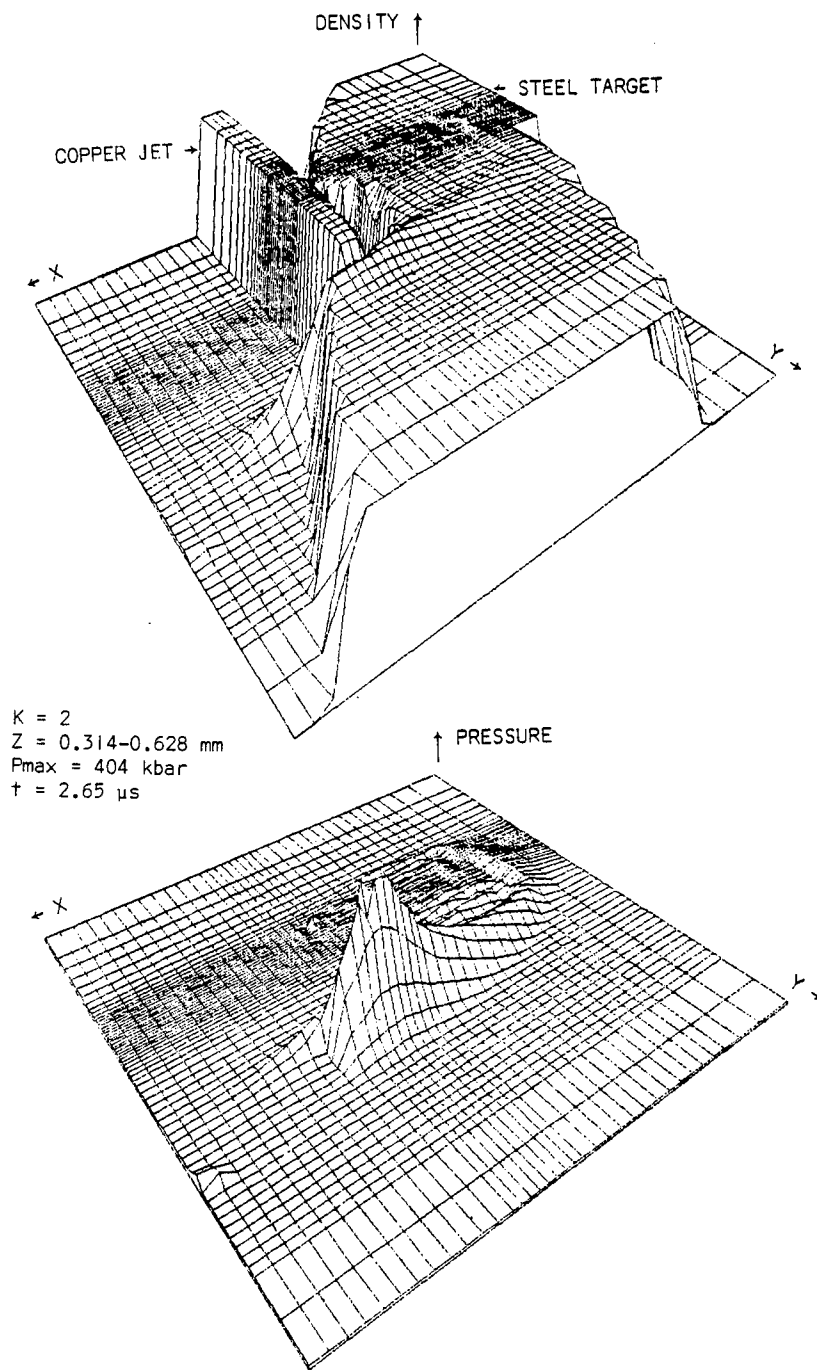
Figure 34. Density and Pressure Fields

44

DENSITY ↑

← STEEL TARGET

← X

Y →

K = 4
Z = 0.942-1.256 mm
Pmax = 304 kbar
t = 2.65 µs

↑ PRESSURE

← X

Y →
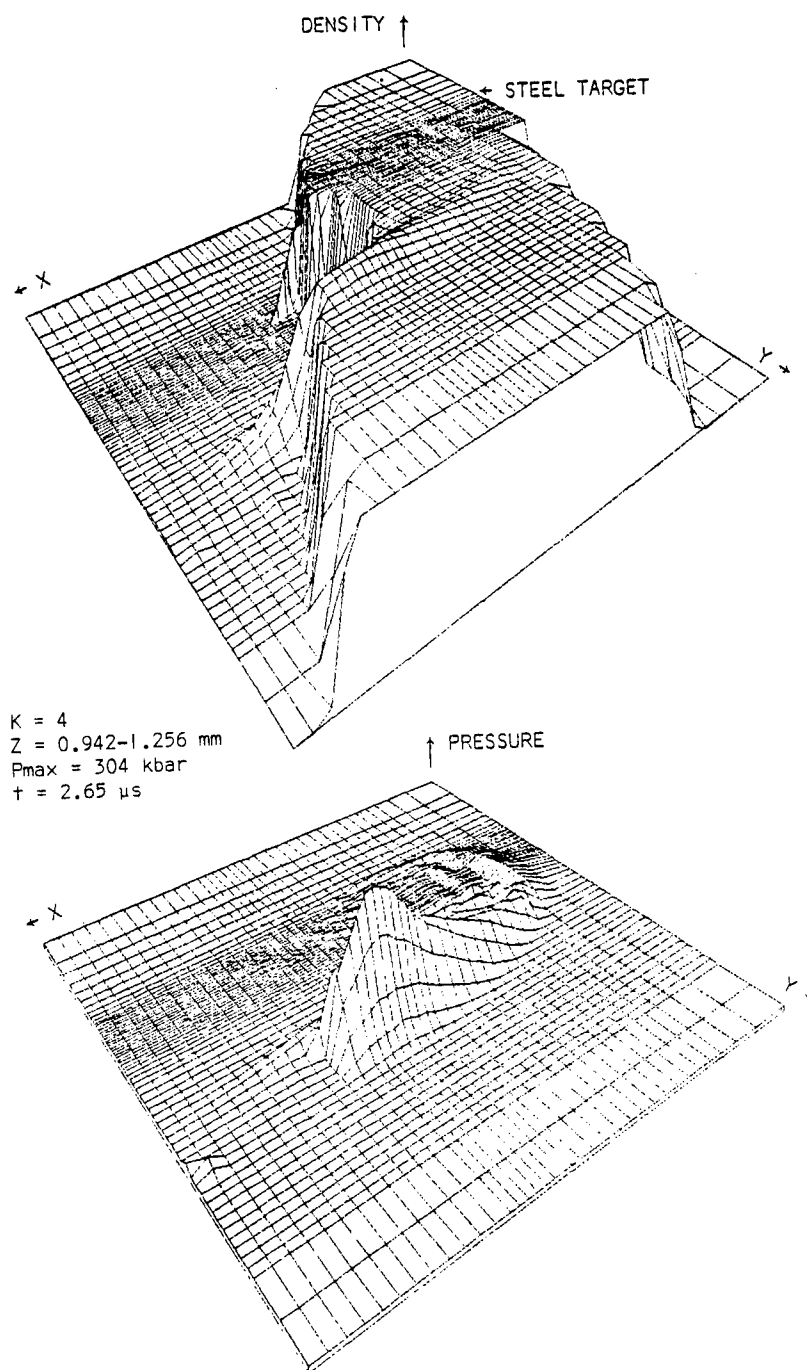
Figure 35. Density and Pressure Fields

DENSITY ↑

← STEEL TARGET

← X

Y

K = 5
Z = 1.256-1.601 mm
Pmax = 255 kbar
t = 2.65 μs

↑ PRESSURE

← X

Y
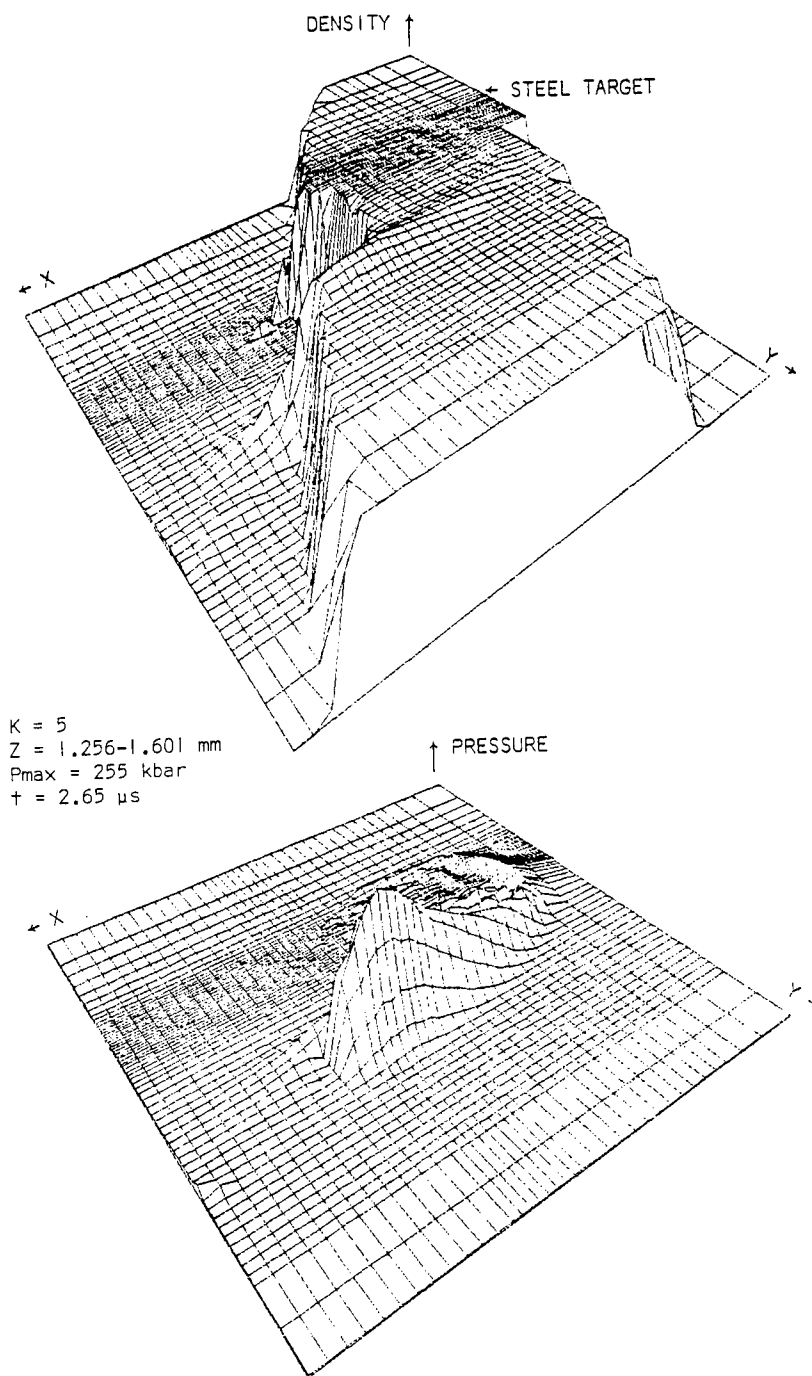
Figure 36. Density and Pressure Fields

46

DENSITY ↑

← STEEL TARGET

← X

Y →

K = 7
Z = 1.981-2.399 mm
Pmax = 178 kbar
t = 2.65 μs

↑ PRESSURE

← X

Y →
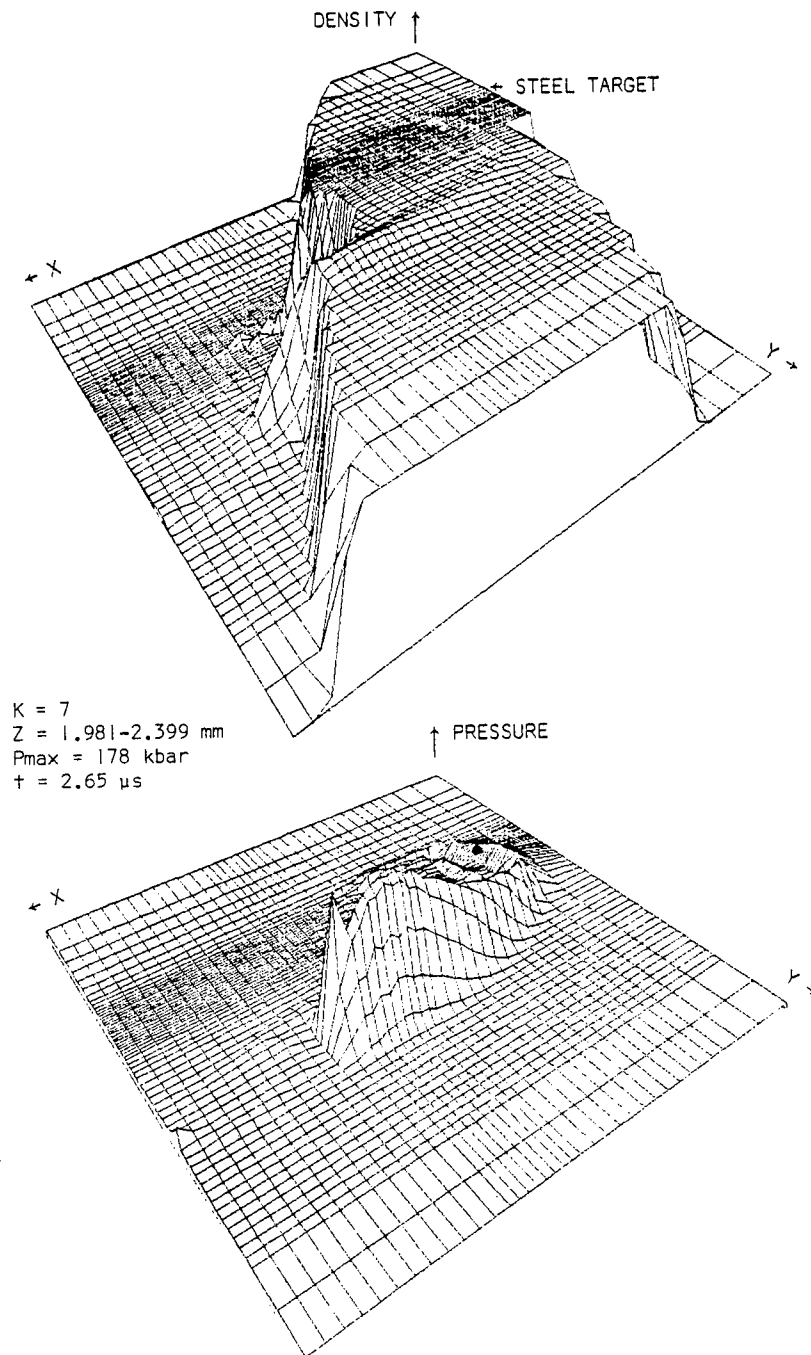
Figure 37. Density and Pressure Fields

47

DENSITY ↑

STEEL TARGET

← X

Y →

K = 8
Z = 2.399-2.859 mm
Pmax = 150 kbar
t = 2.65 µs

↑ PRESSURE

← X

Y →
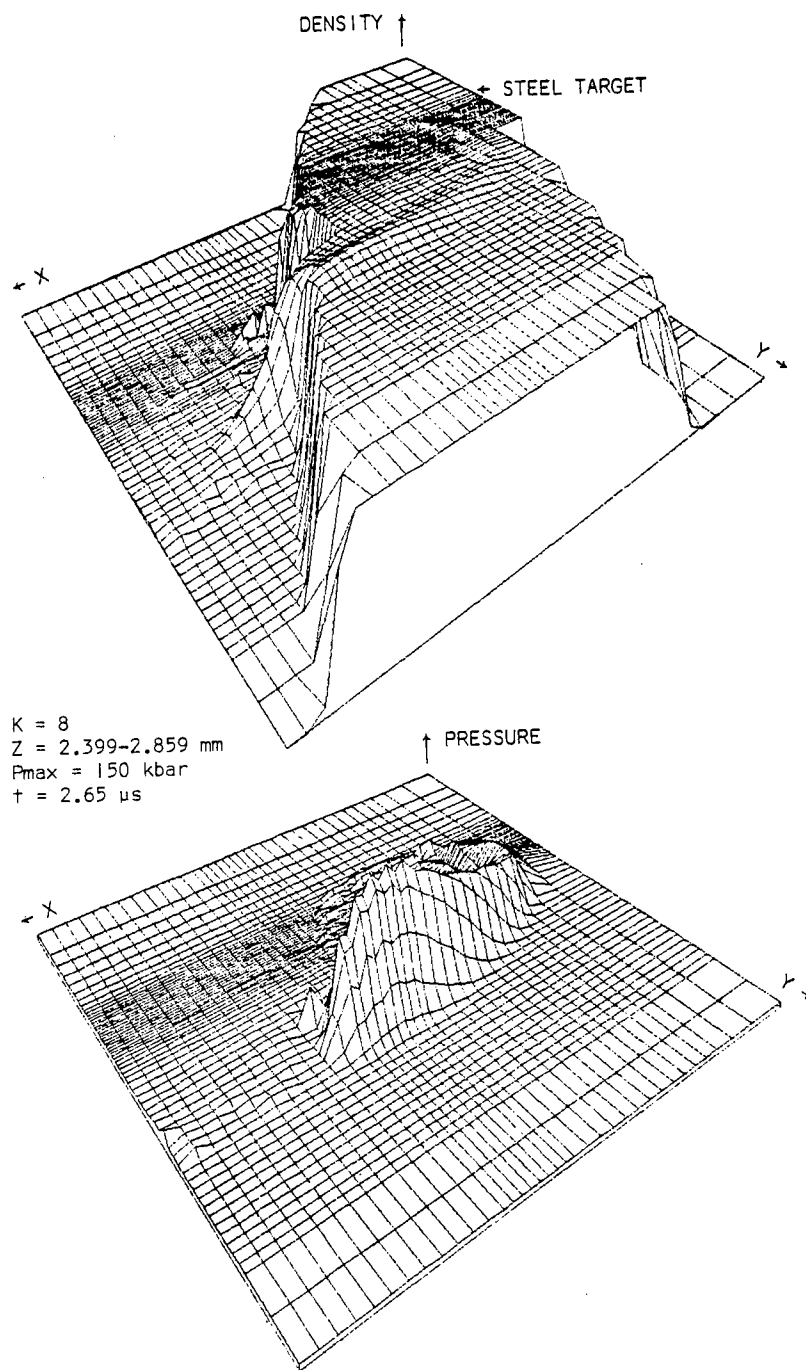
Figure 38.   Density and Pressure Fields

48

DENSITY ↑

← STEEL TARGET

← X

Y →

K = 9
Z = 2.859-3.365 mm
Pmax = 131 kbar
t = 2.65 μs

↑ PRESSURE

← X

Y →
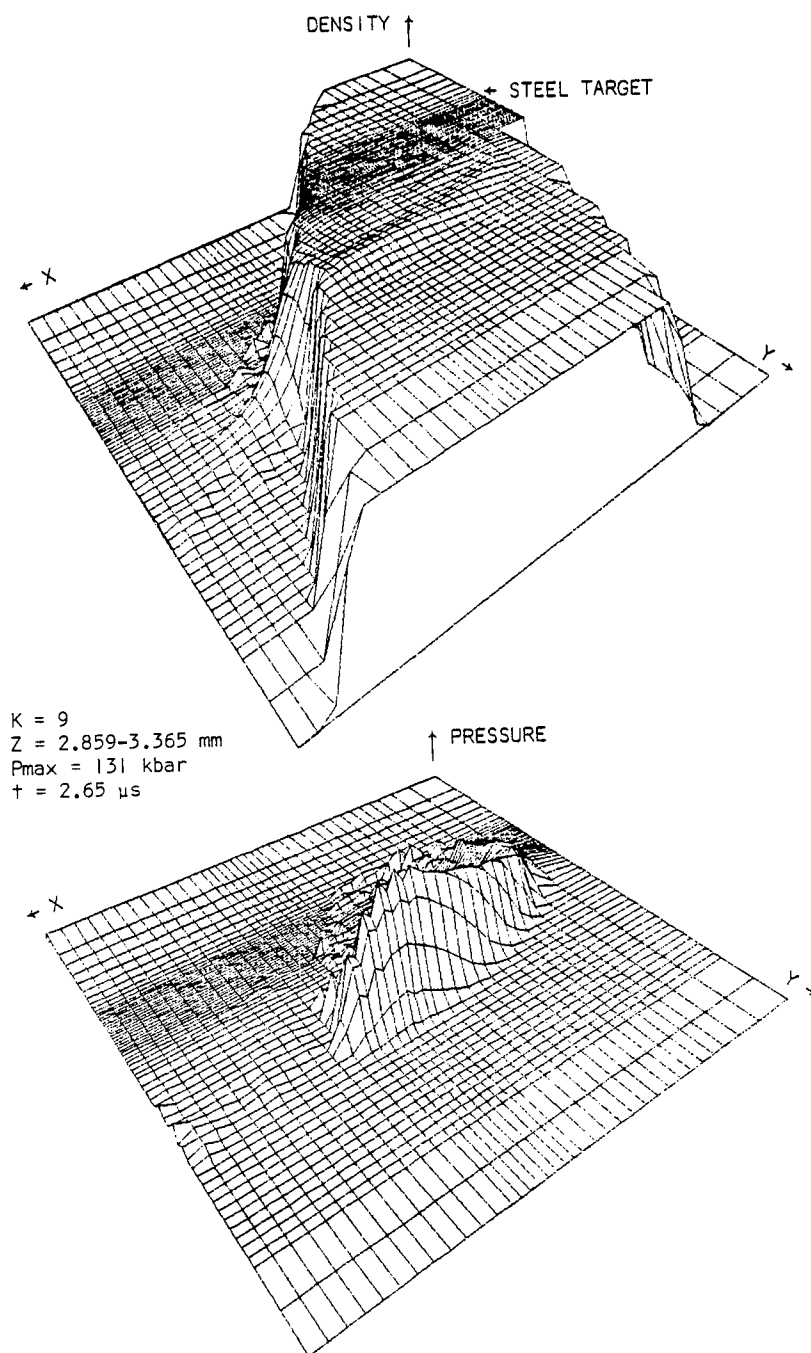
Figure 39. Density and Pressure Fields

49

DENSITY ↑

← STEEL TARGET

← X

Y →

K = 10
Z = 3.365-3.921 mm
Pmax = 105 kbar
t = 2.65 μs

↑ PRESSURE

← X

Y →
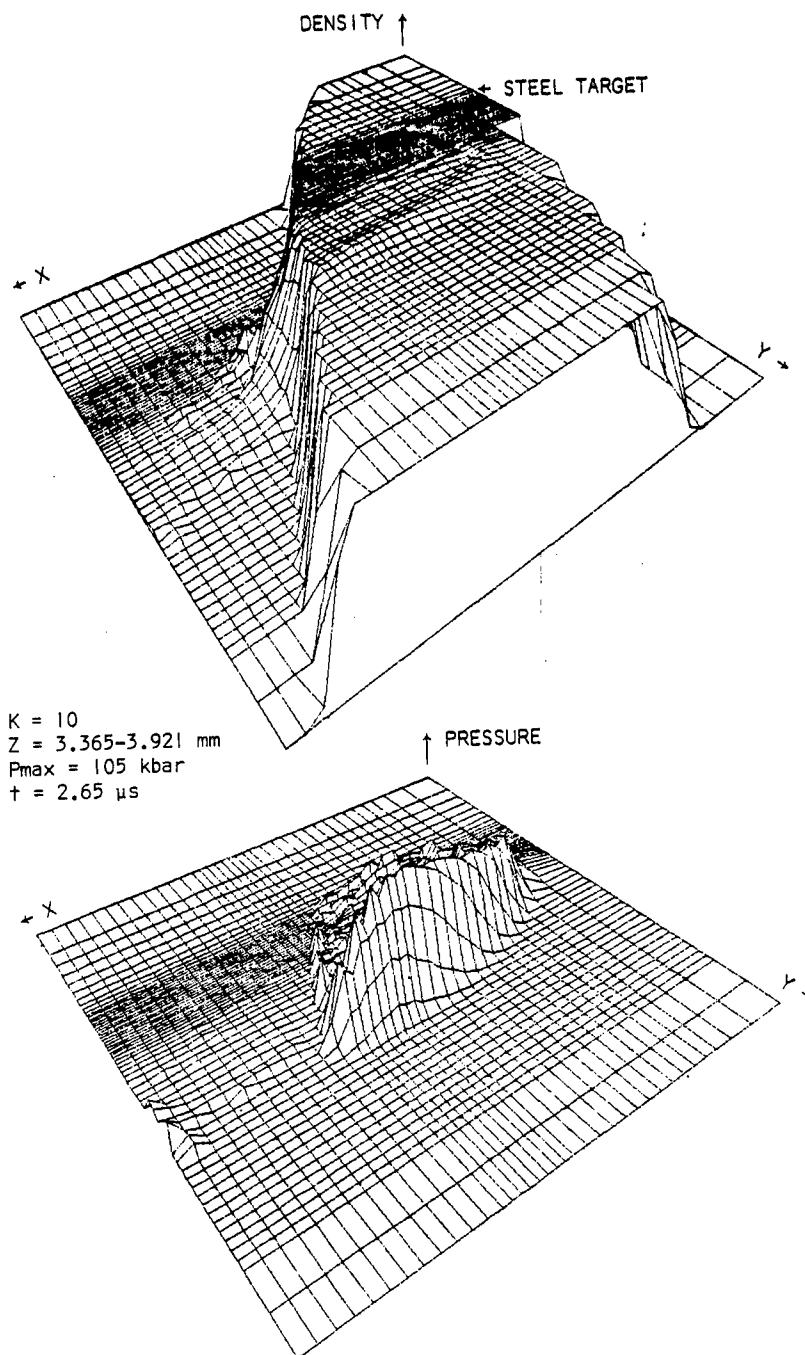
Figure 40. Density and Pressure Fields

DENSITY ↑

← STEEL TARGET

← X

Y →

K = 11
Z = 3.921-4.540 mm
Pmax = 88 kbar
t = 2.65 μs

↑ PRESSURE

← X

Y →
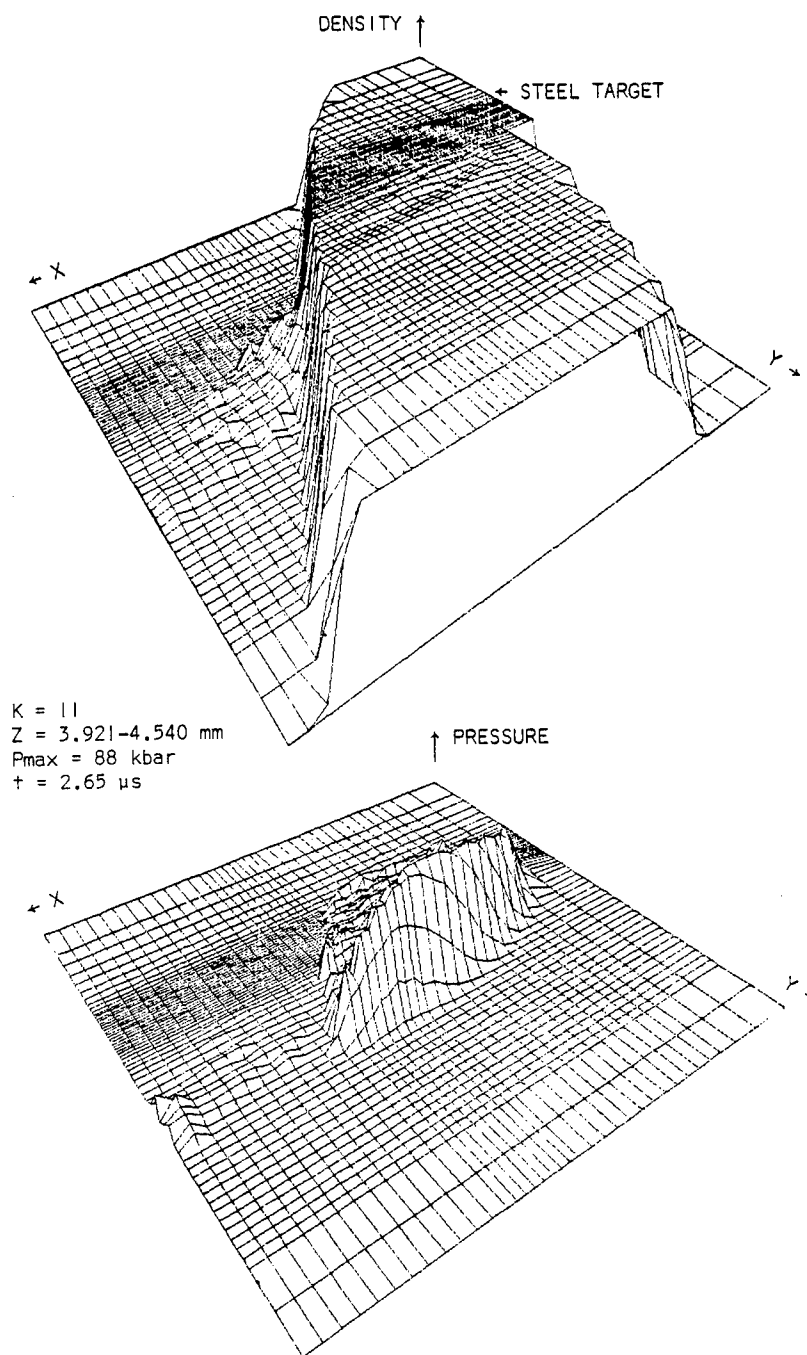
Figure 41. Density and Pressure Fields

51

DENSITY ↑

← STEEL TARGET

← X

Y →

K = 12
Z = 4.540–5.213 mm
Pmax = 101 kbar
t = 2.65 μs

↑ PRESSURE

← X

Y →
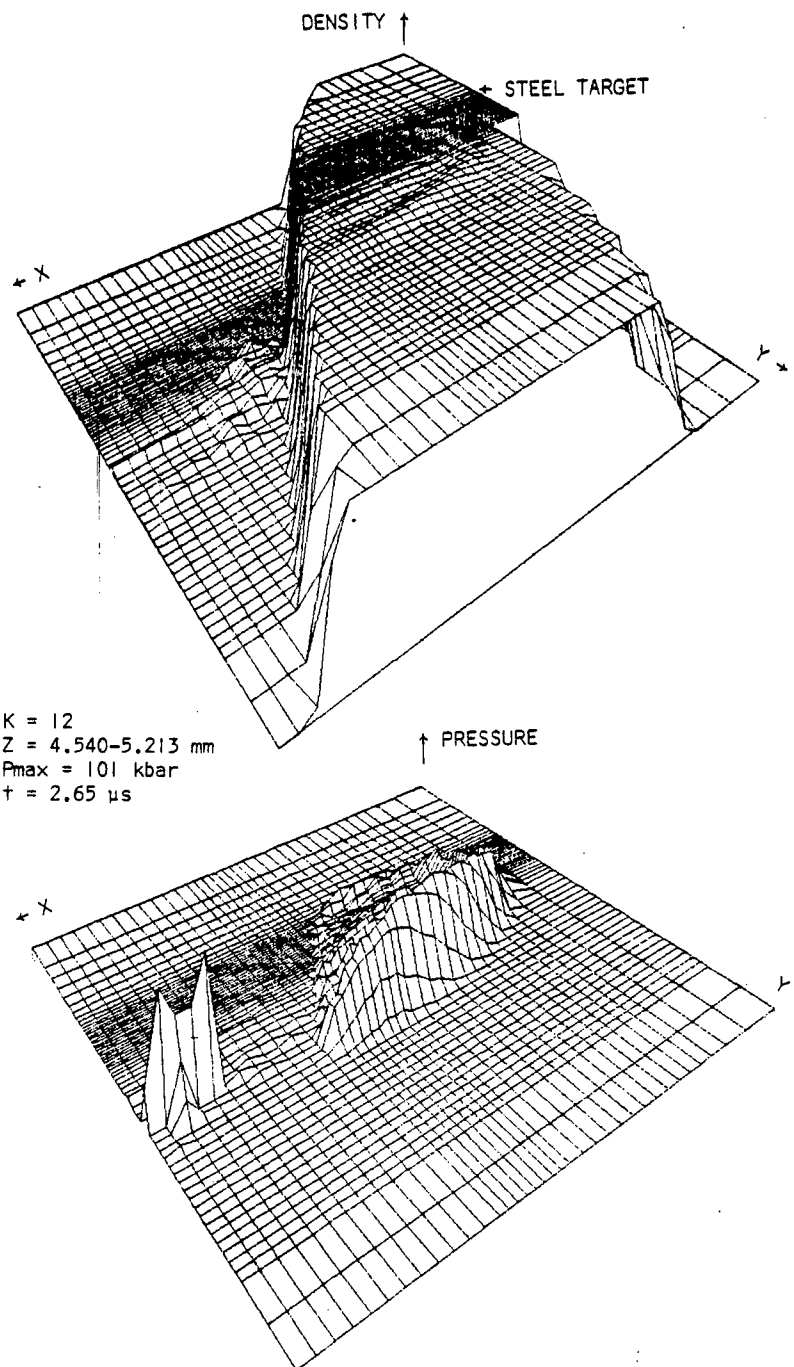
Figure 42.   Density and Pressure Fields

52

DENSITY ↑

STEEL TARGET

X

Y

K = 13
Z = 5.213-5.953 mm
Pmax = 67 kbar
t = 2.65 μs

↑ PRESSURE

X

Y
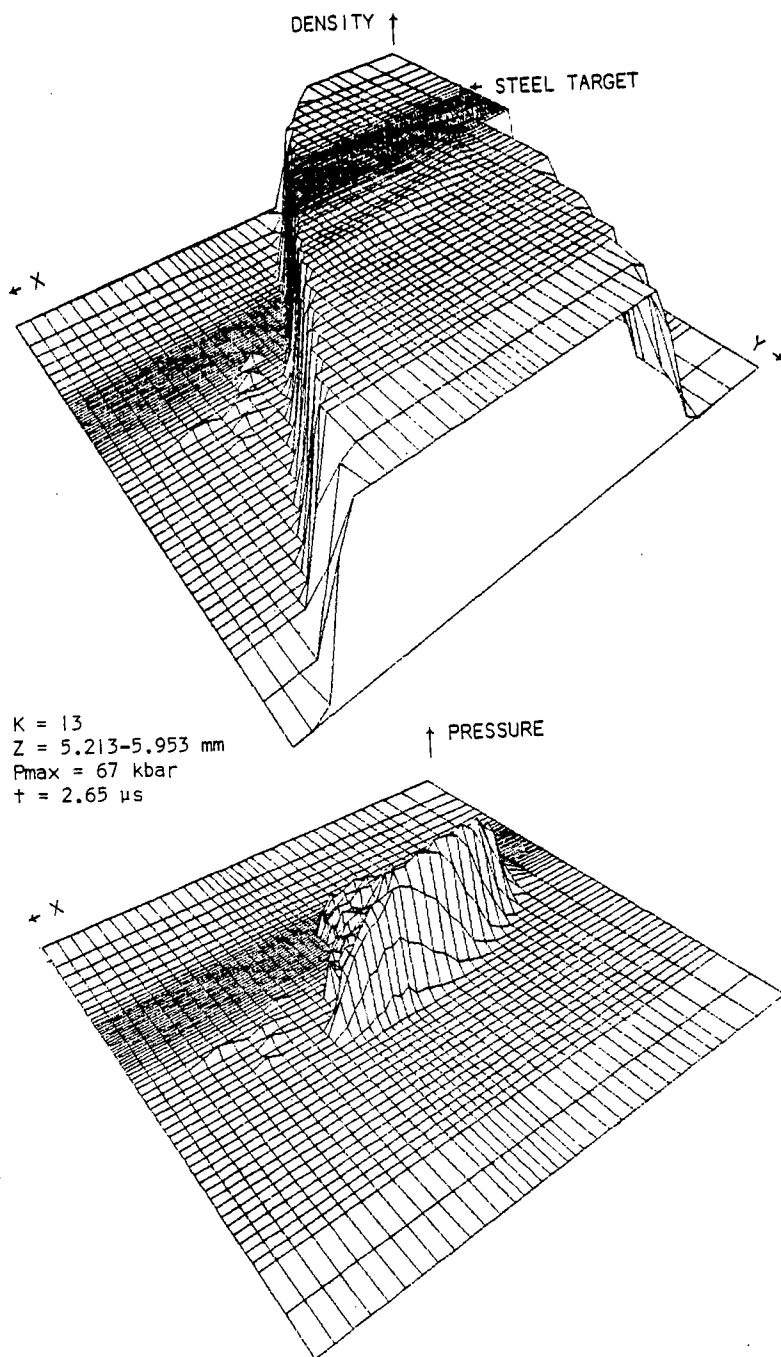
Figure 43. Density and Pressure Fields

53

DENSITY ↑

STEEL TARGET

X

Y

K = 14
Z = 5.953-6.767 mm
Pmax = 62 kbar
t = 2.65 µs

↑ PRESSURE

X

Y
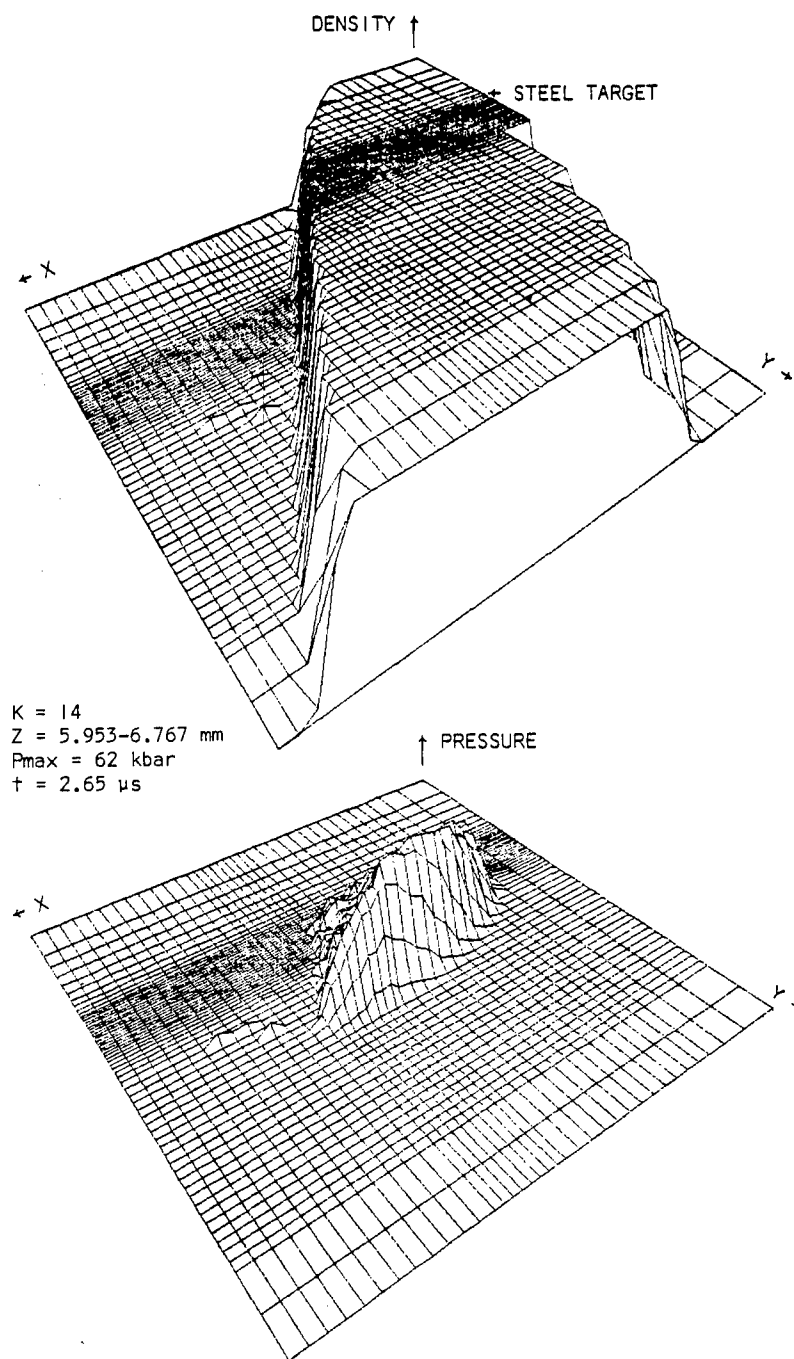
Figure 44. Density and Pressure Fields

54

DENSITY ↑

STEEL TARGET

X

Y

K = 15
Z = 6.767–8.367 mm
Pmax = 29 kbar
t = 2.65 μs

↑ PRESSURE

X

Y
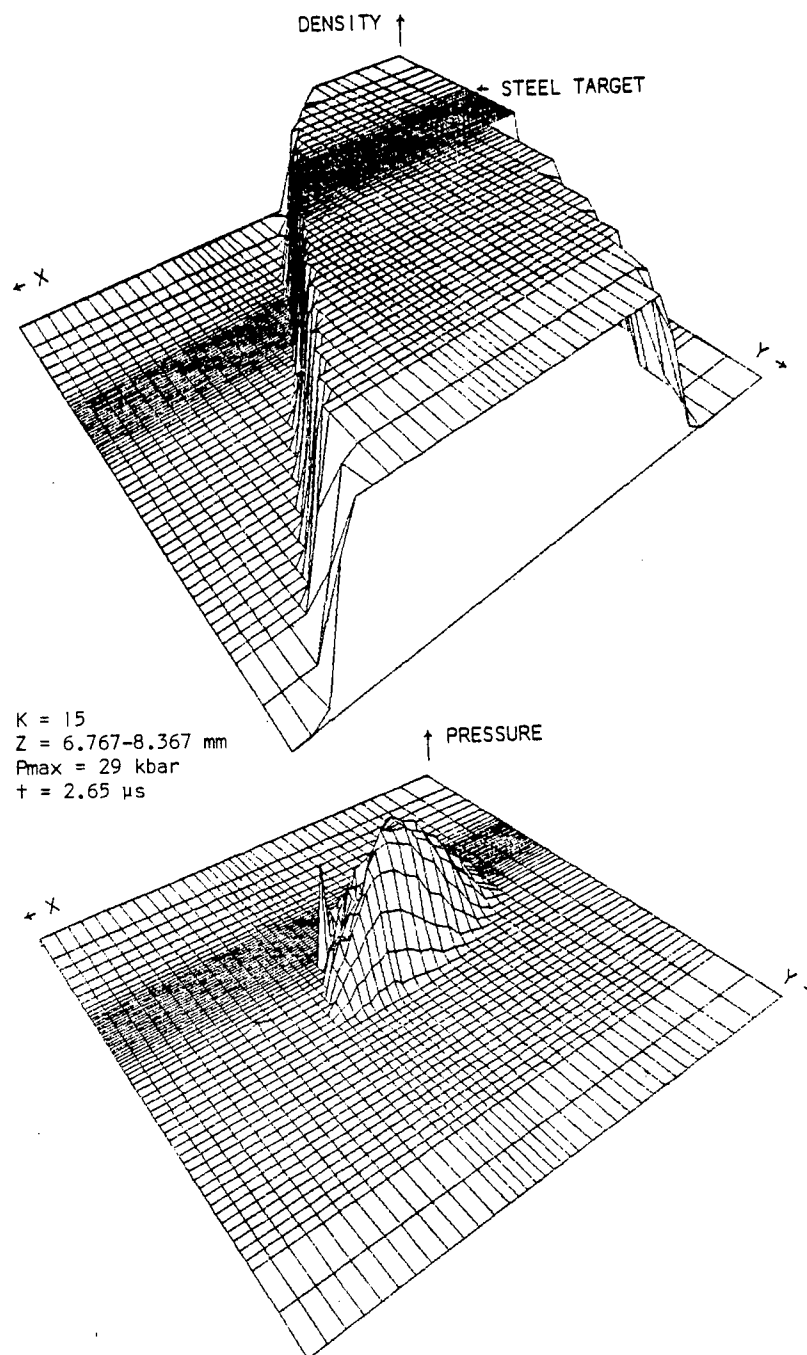
Figure 45. Density and Pressure Fields

55

DENSITY ↑

← STEEL TARGET

COPPER JET →

Y ↗

K = 1
Z = 0.0-0.314 mm
Pmax = 406 kbar
t = 2.65 μs

↑ PRESSURE

Y ↗
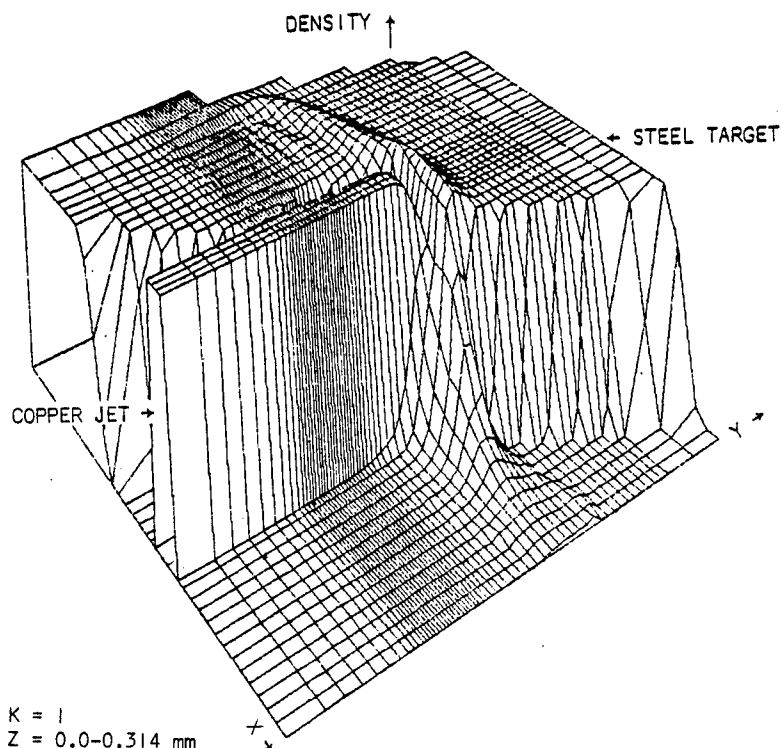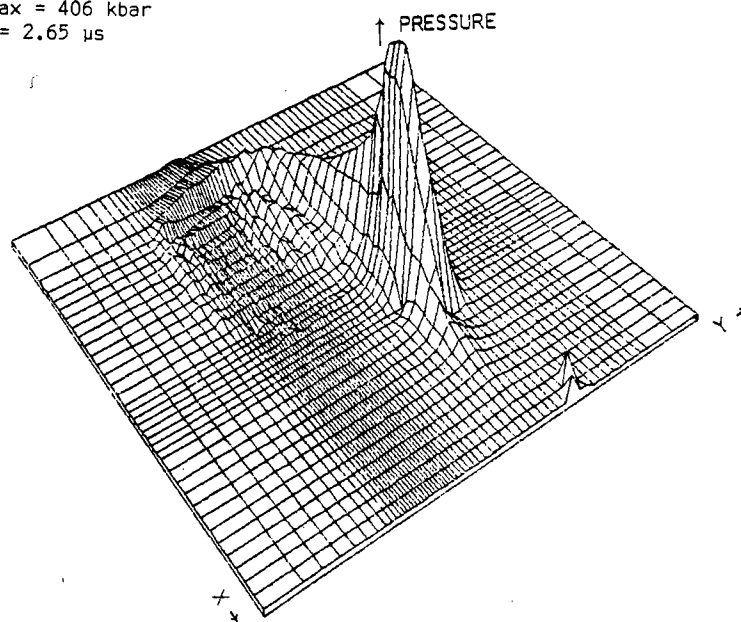
Figure 46. Density and Pressure Fields

DENSITY ↑

← STEEL TARGET

COPPER JET →

K = 2
Z = 0.314-0.628 mm
Pmax = 404 kbar
t = 2.65 μs
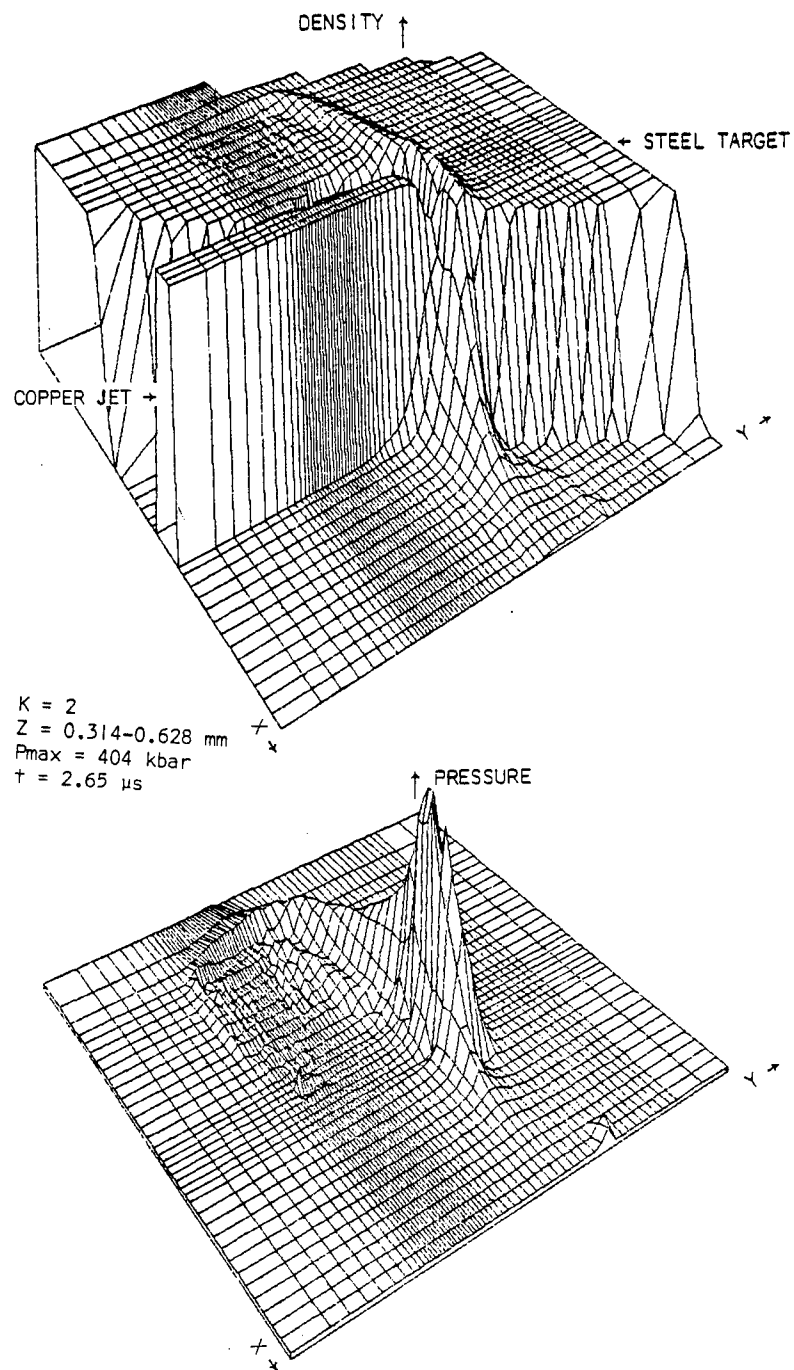
↑ PRESSURE

Figure 47.   Density and Pressure Fields

DENSITY ↑

← STEEL TARGET

Y

K = 4
Z = 0.942-1.256 mm
Pmax = 304 kbar
t = 2.65 μs

↑ PRESSURE

Y
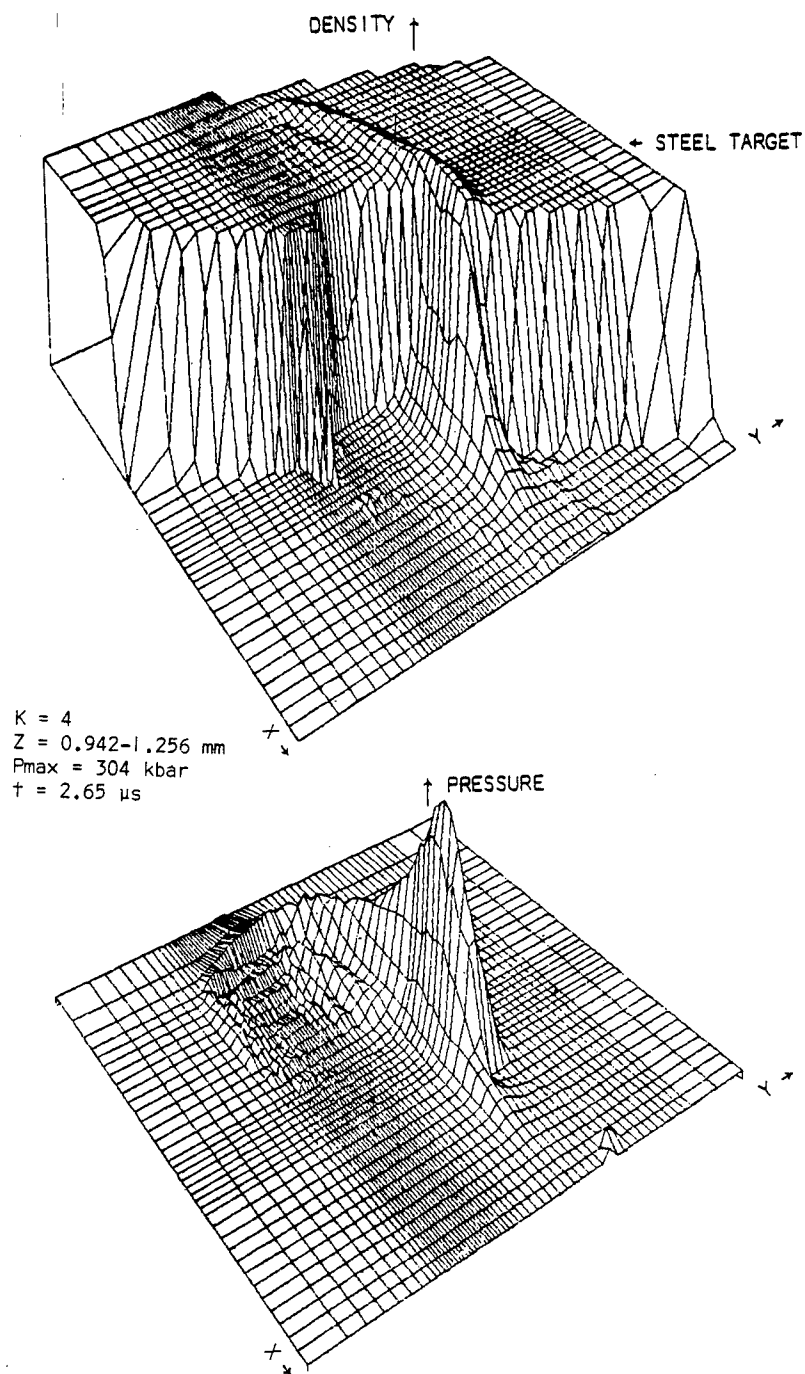
Figure 48. Density and Pressure Fields

58

DENSITY ↑

← STEEL TARGET

Y

K = 5
Z = 1.256–1.601 mm
Pmax = 255 kbar
t = 2.65 µs

↑ PRESSURE

Y
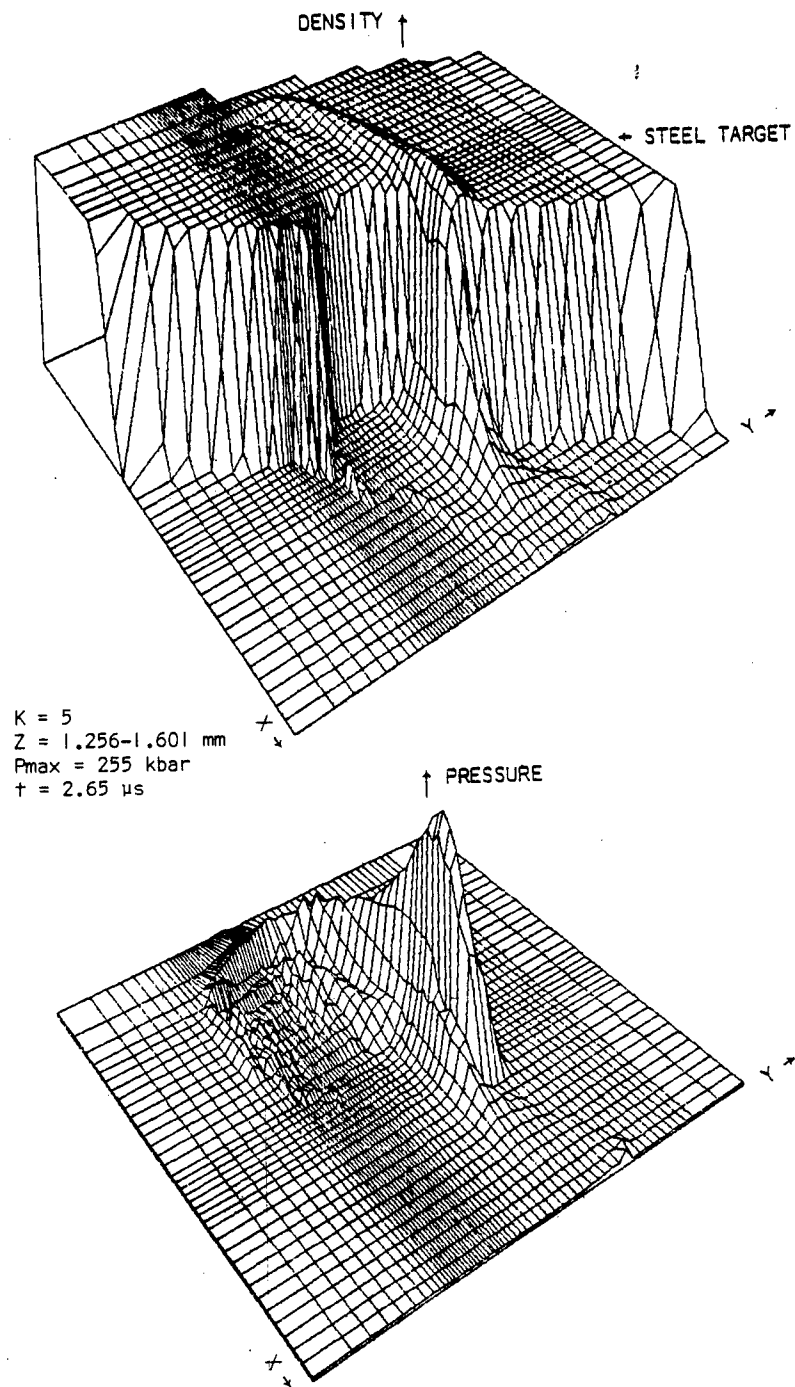
Figure 49.   Density and Pressure Fields

59

DENSITY ↑

← STEEL TARGET

K = 7
Z = 1.981-2.399 mm
Pmax = 178 kbar
t = 2.65 μs
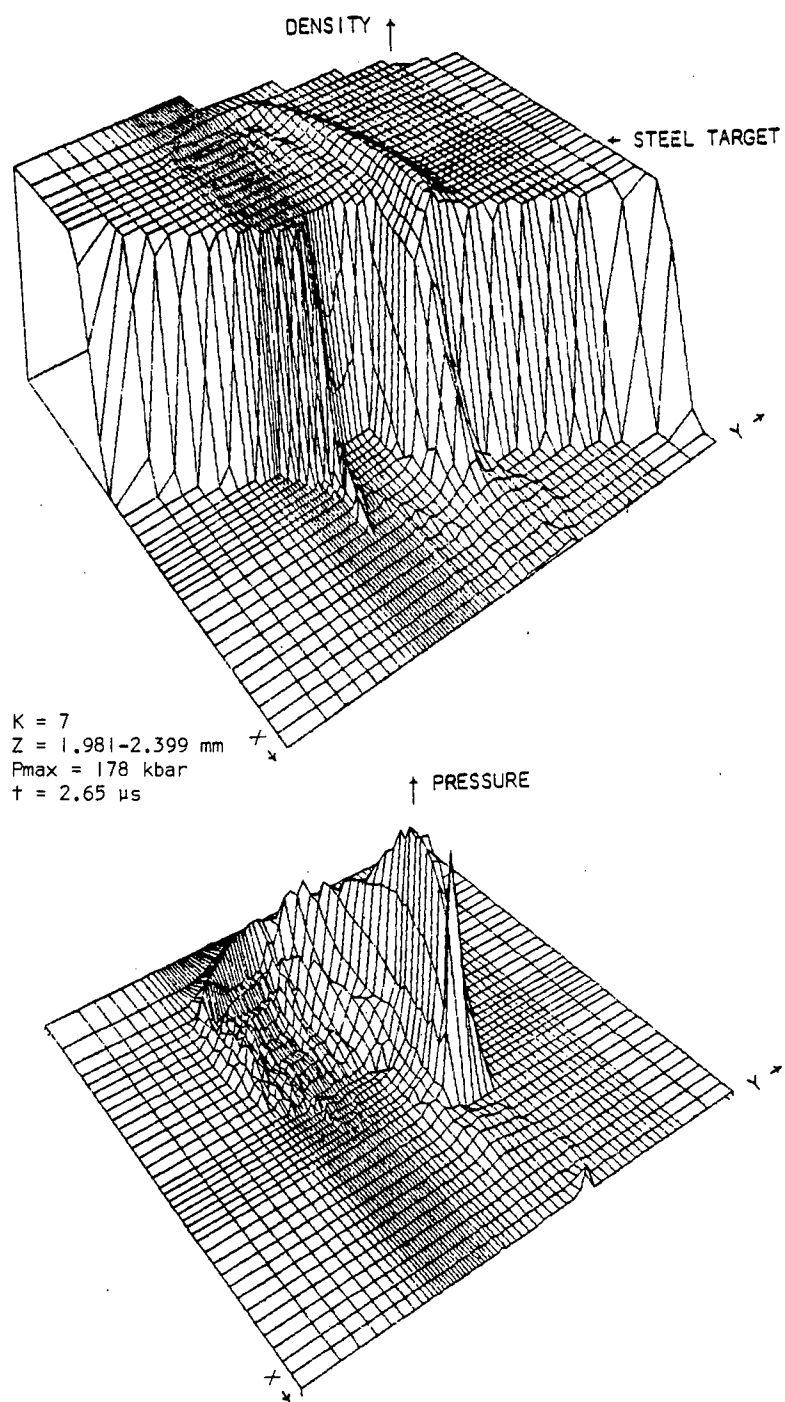
↑ PRESSURE

Figure 50.   Density and Pressure Fields

60

DENSITY ↑

← STEEL TARGET

Y →

K = 8
Z = 2.399–2.859 mm
Pmax = 150 kbar
t = 2.65 μs

↑ PRESSURE

Y →
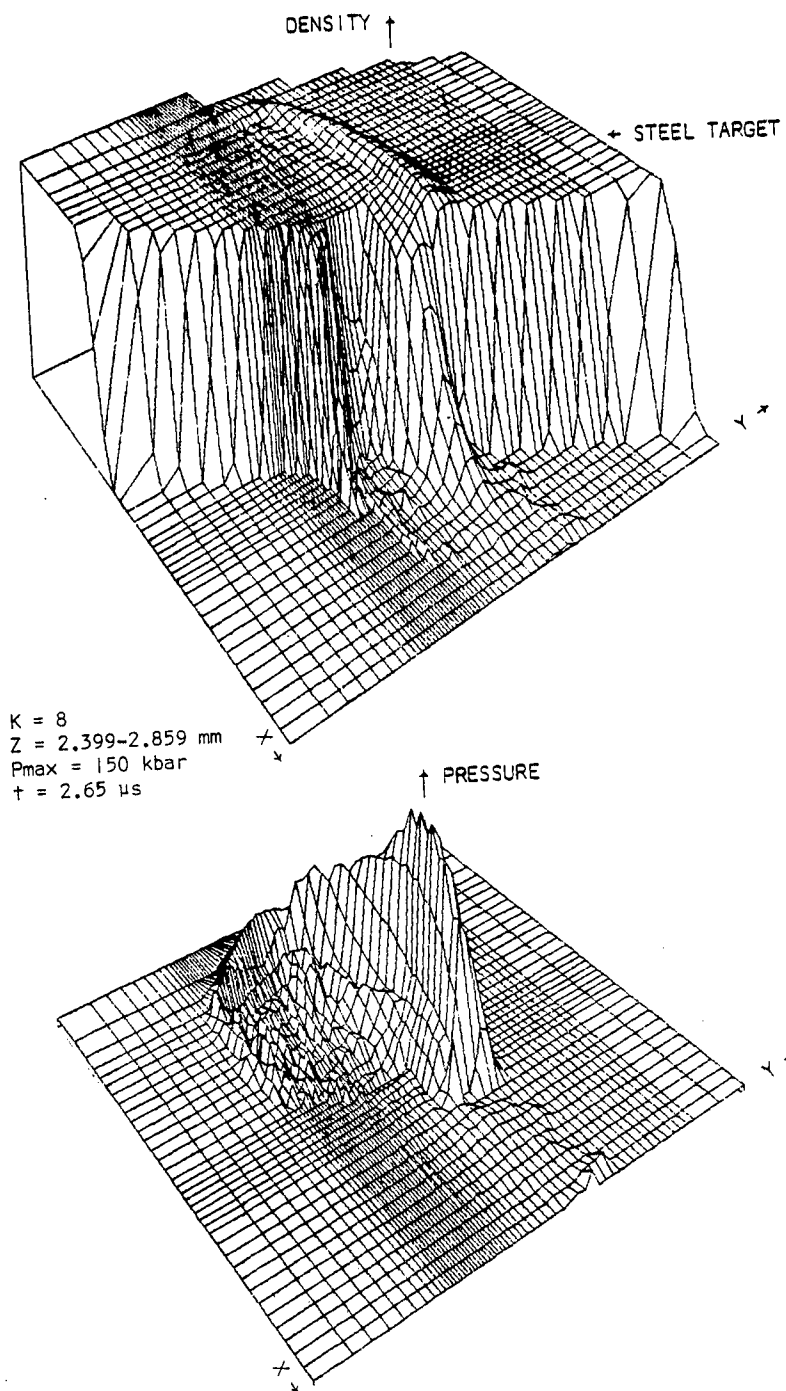
Figure 51. Density and Pressure Fields

DENSITY ↑

← STEEL TARGET

Y

K = 9
Z = 2.859-3.365 mm
Pmax = 131 kbar
t = 2.65 μs

↑ PRESSURE

Y
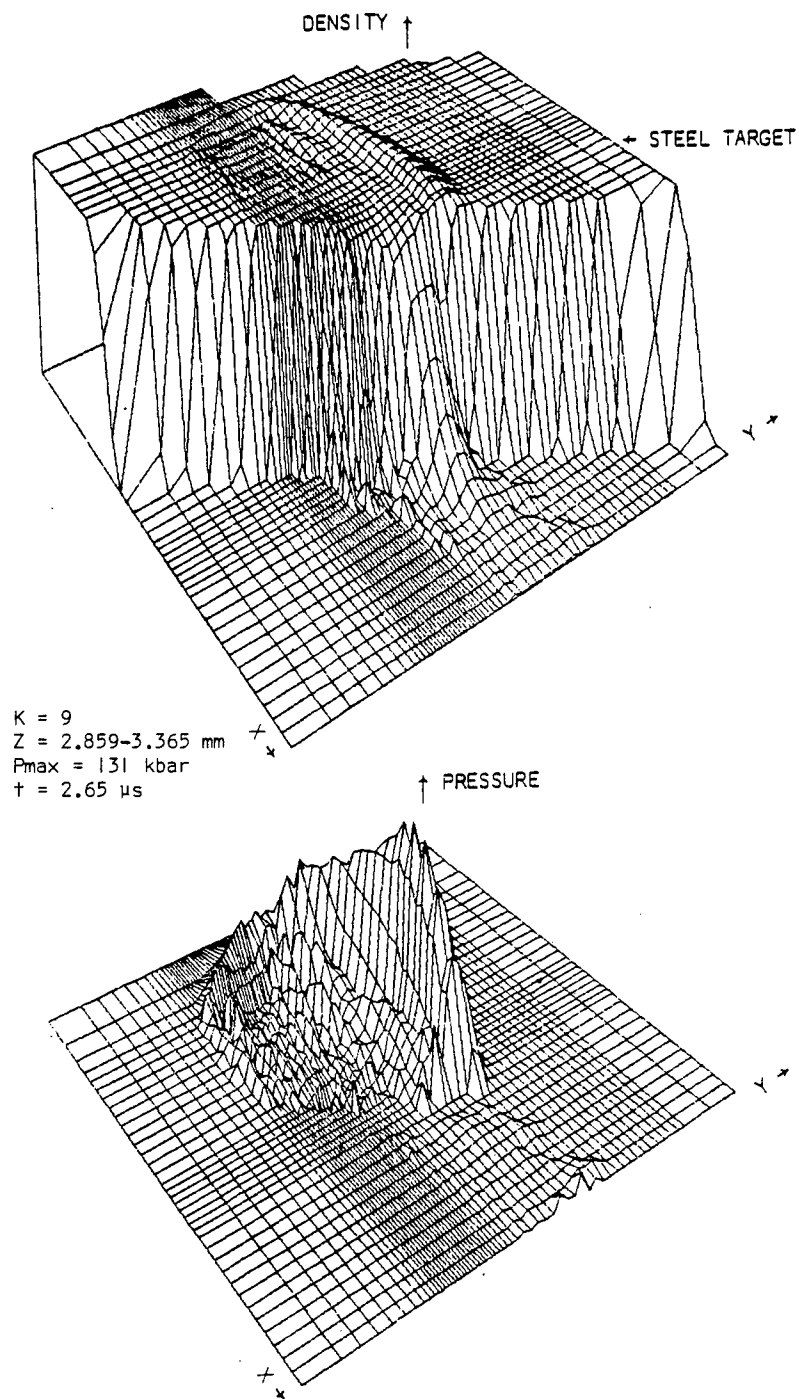
Figure 52.   Density and Pressure Fields

DENSITY ↑

← STEEL TARGET

Y ↗

K = 10
Z = 3.365-3.921 mm
Pmax = 105 kbar
t = 2.65 µs

↑ PRESSURE

Y ↗
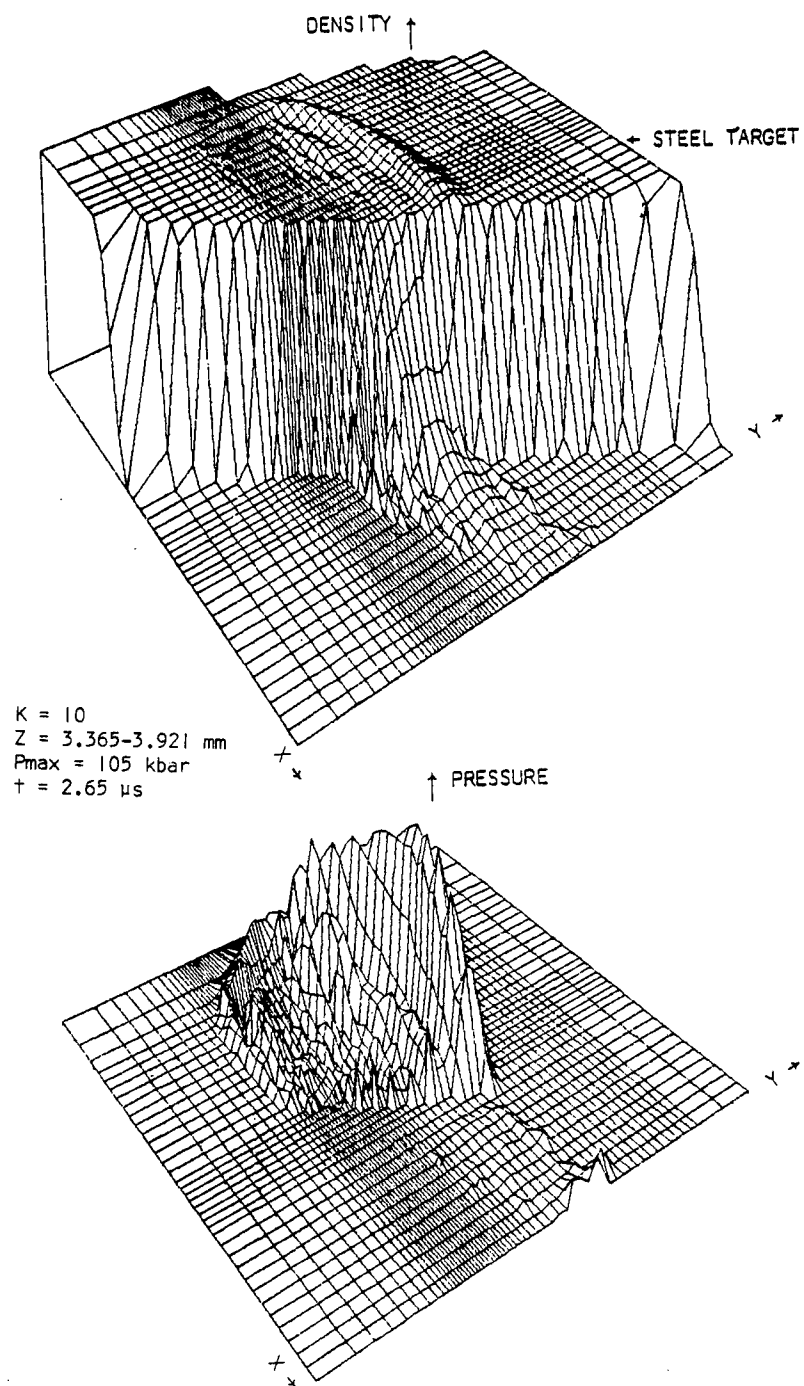
Figure 53. Density and Pressure Fields

63

DENSITY ↑

← STEEL TARGET

Y ↗

K = 11
Z = 3.921-4.540 mm
Pmax = 88 kbar
t = 2.65 μs

↑ PRESSURE

Y ↗
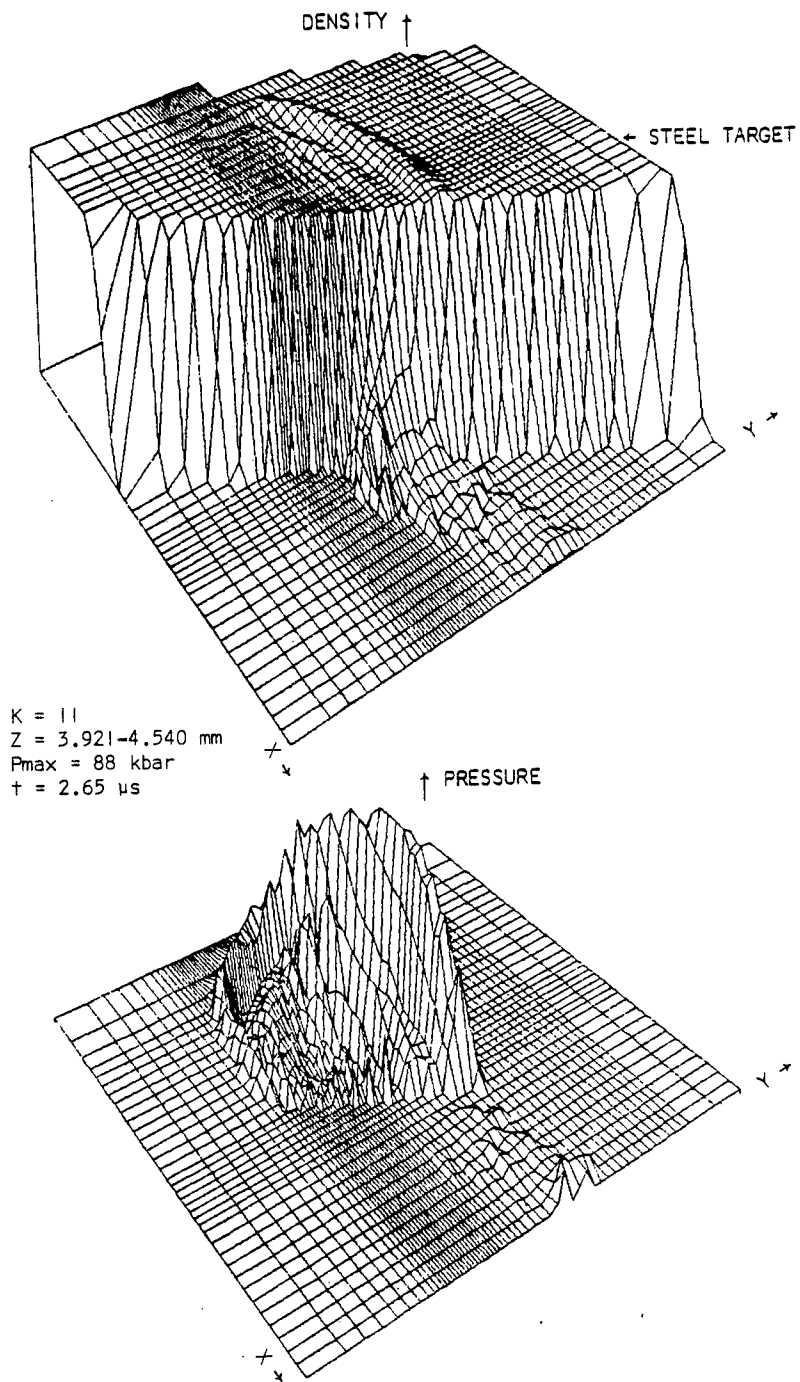
Figure 54.   Density and Pressure Fields

DENSITY ↑

← STEEL TARGET

Y ↗

K = 12
Z = 4.540-5.213 mm
Pmax = 101 kbar
t = 2.65 μs

↑ PRESSURE

Y ↗
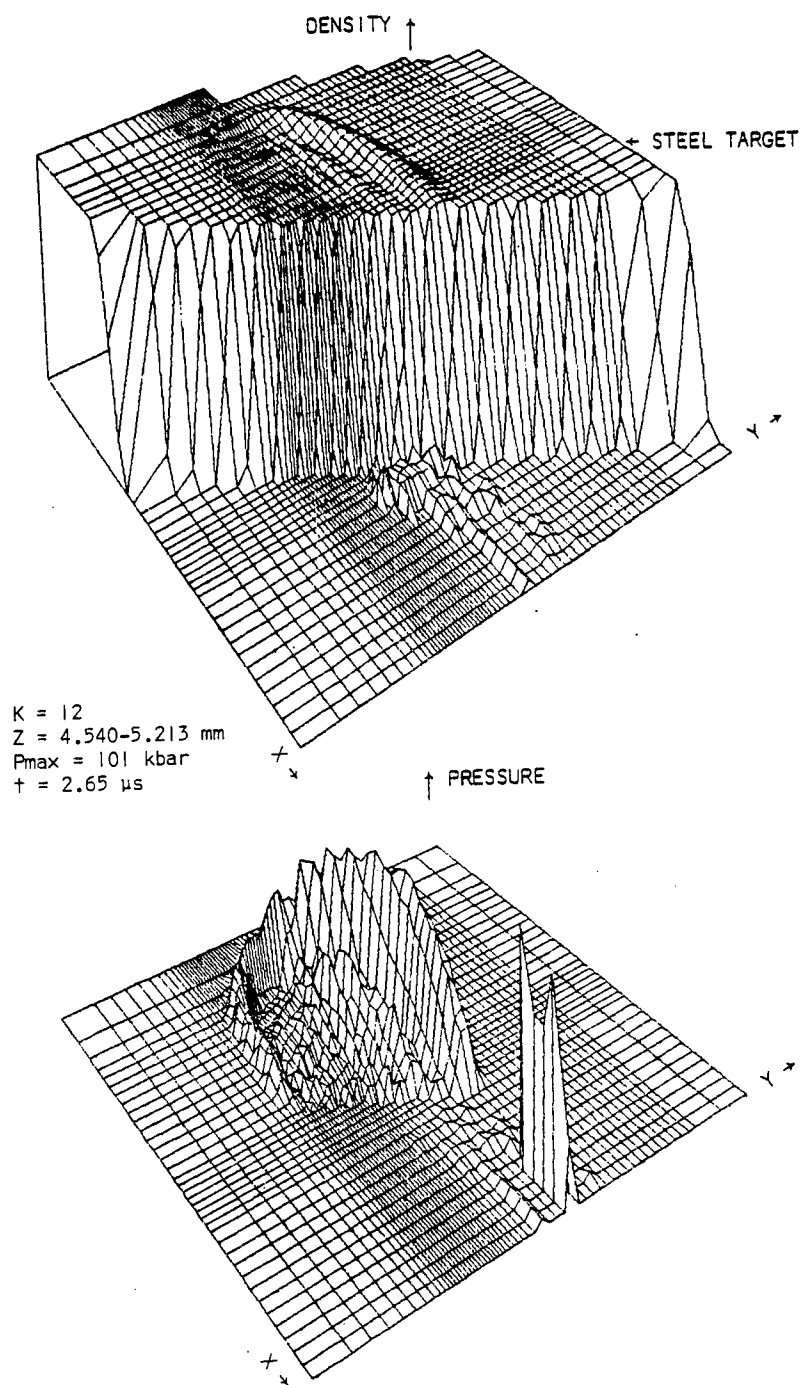
Figure 55. Density and Pressure Fields

65

DENSITY ↑

← STEEL TARGET

Y →

K = 13
Z = 5.213-5.953 mm
Pmax = 67 kbar
t = 2.65 µs

↑ PRESSURE

Y →
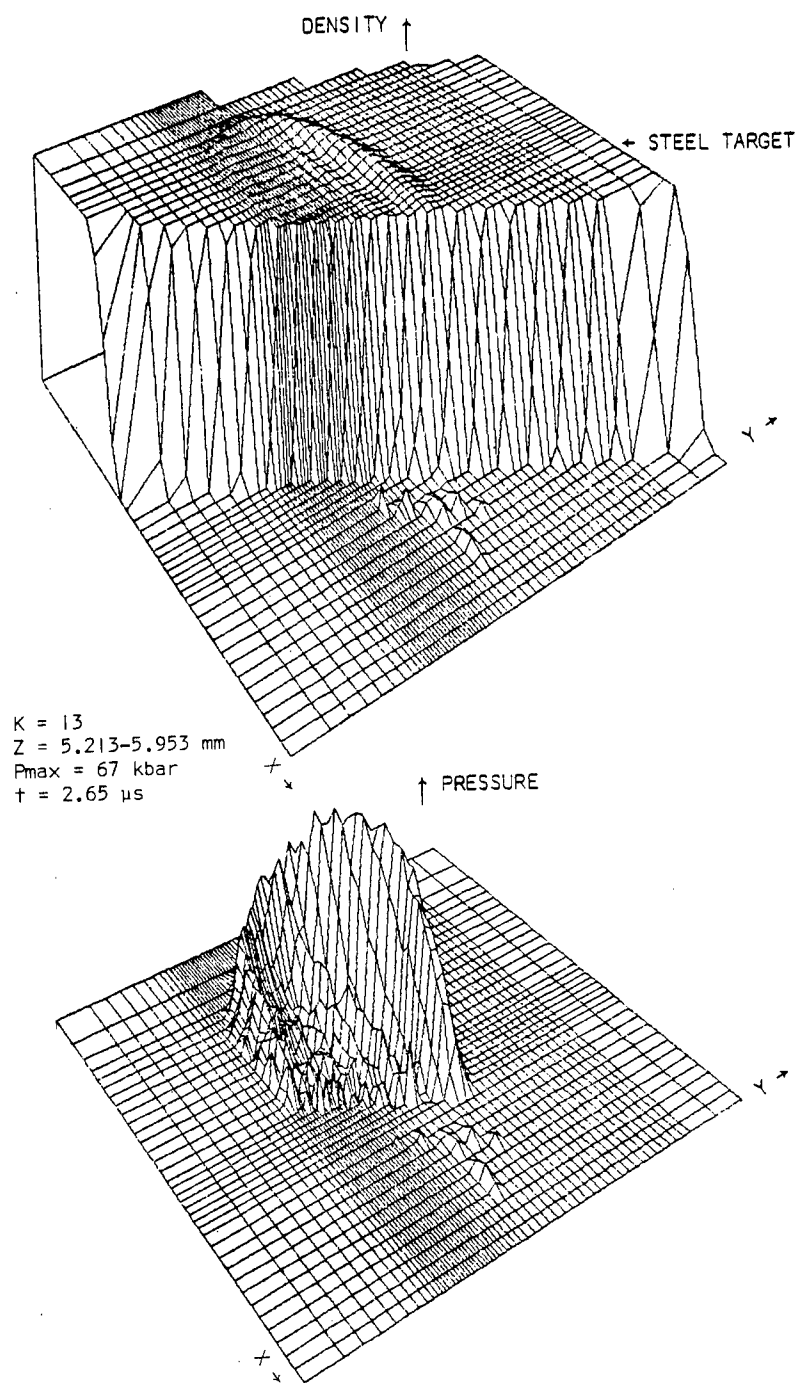
Figure 56.   Density and Pressure Fields

DENSITY ↑

← STEEL TARGET

Y ↗

K = 14
Z = 5.953-6.767 mm
Pmax = 62 kbar
t = 2.65 µs

↑ PRESSURE

Y ↗

Figure 57. Density and Pressure Fields

67

DENSITY ↑

← STEEL TARGET

Y ↗

K = 15
Z = 6.767−8.367 mm
Pmax = 29 kbar
t = 2.65 μs
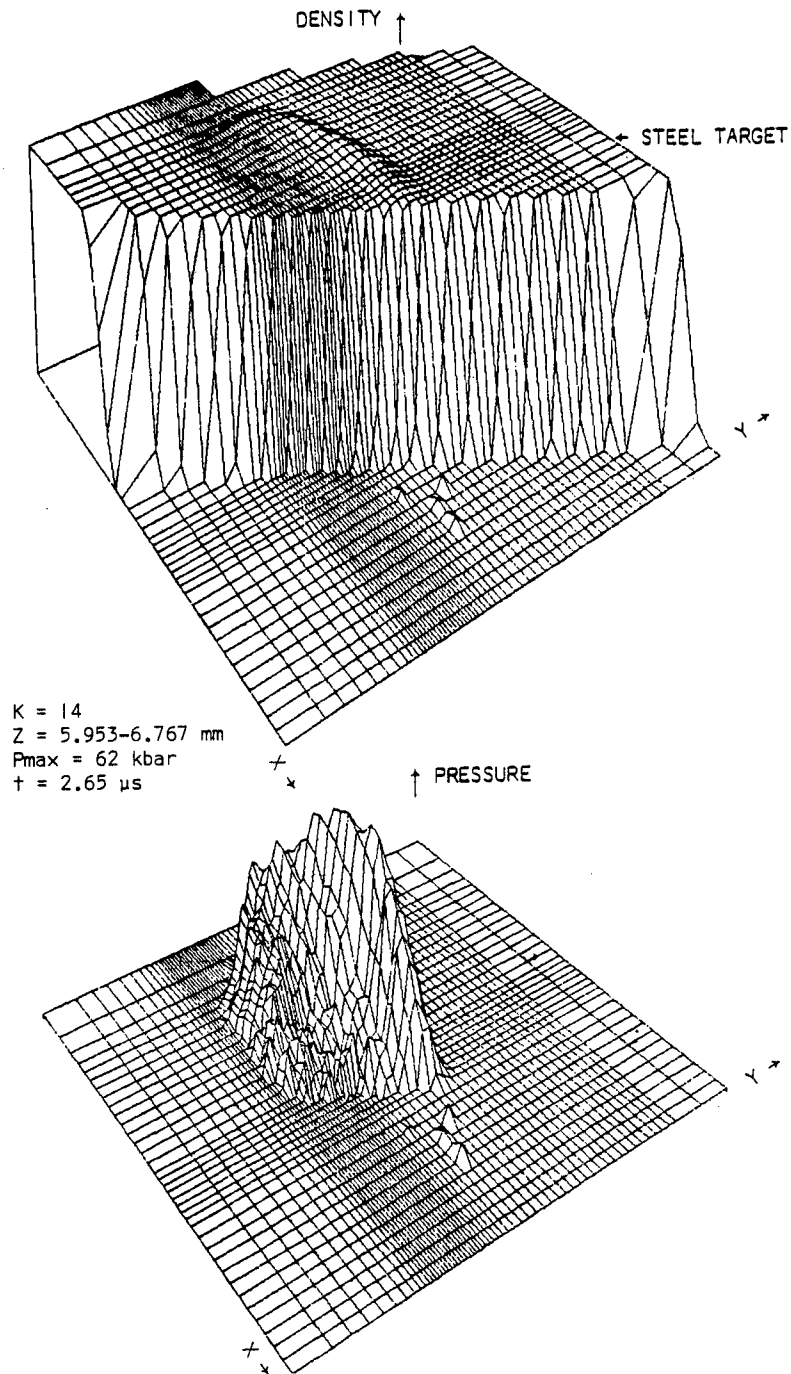
↑ PRESSURE

Y ↗
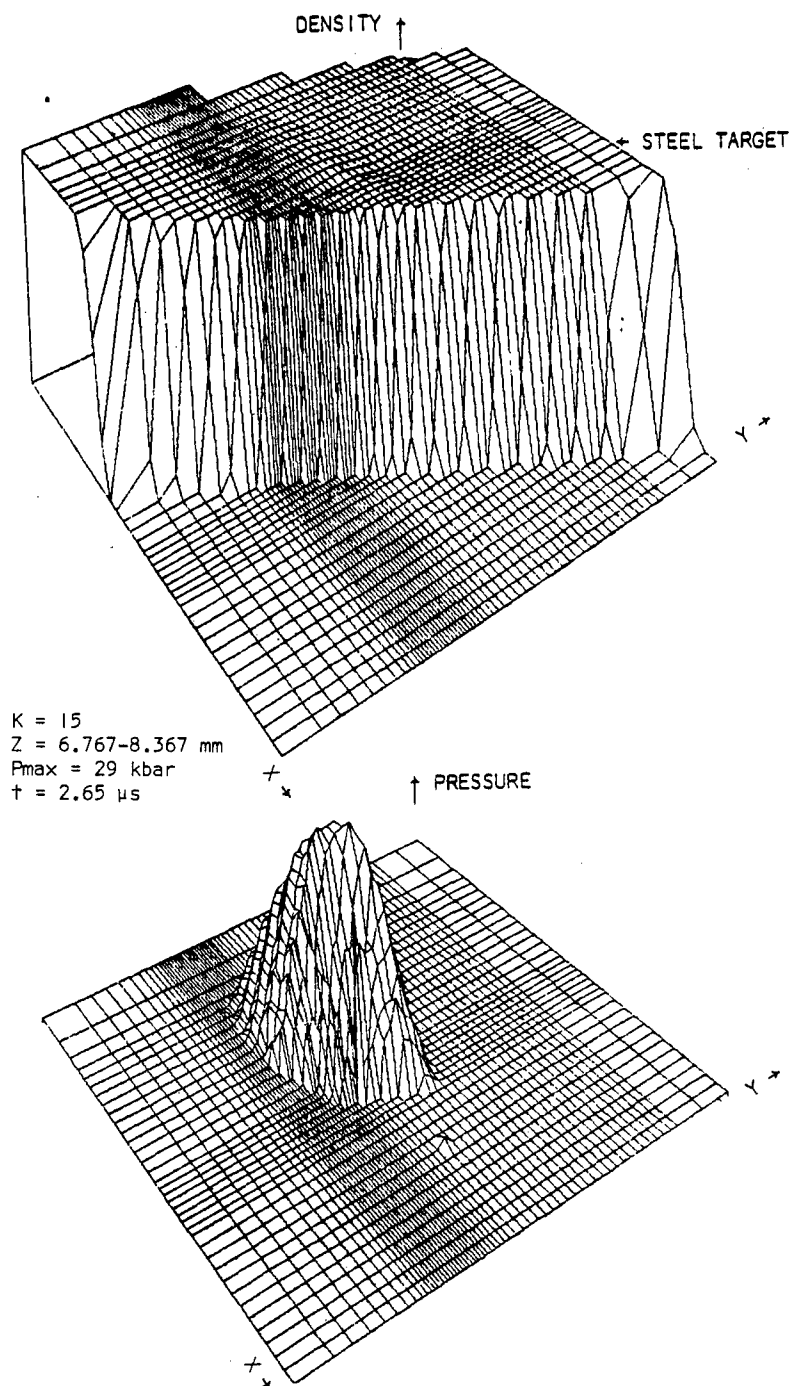
Figure 58. Density and Pressure Fields
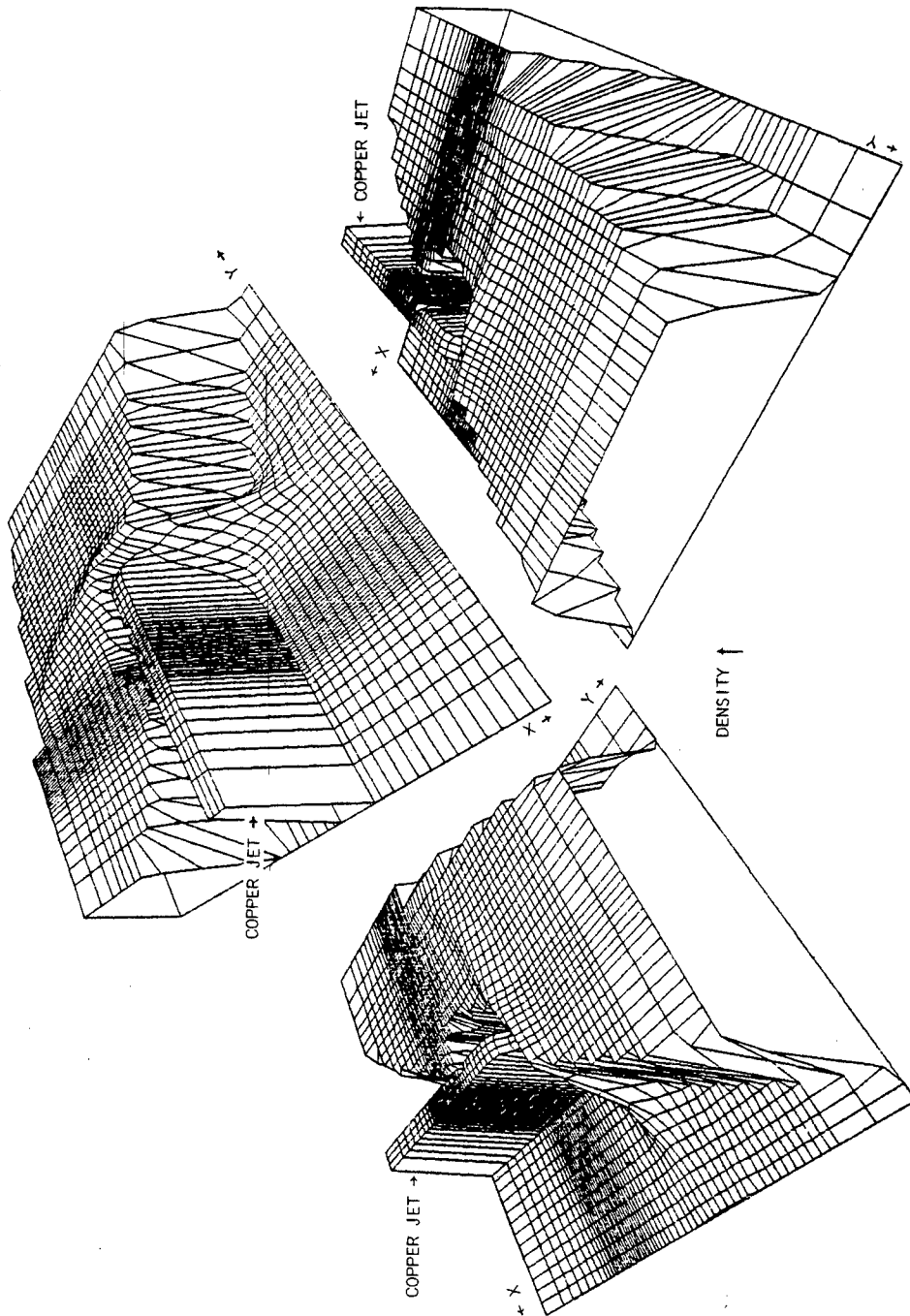
Figure 59. Views of the Density Field at t = 2.65 μs for K = 1

DENSITY

STEEL TARGET

COPPER JET

K = I
Z = 0.0-0.314 mm
Pmax = 388 kbar
t = 2.23 μs

PRESSURE

DENSITY

STEEL TARGET

COPPER JET

K = I
Z = 0.0-0.314 mm
Pmax = 360 kbar
t = 1.55 μs
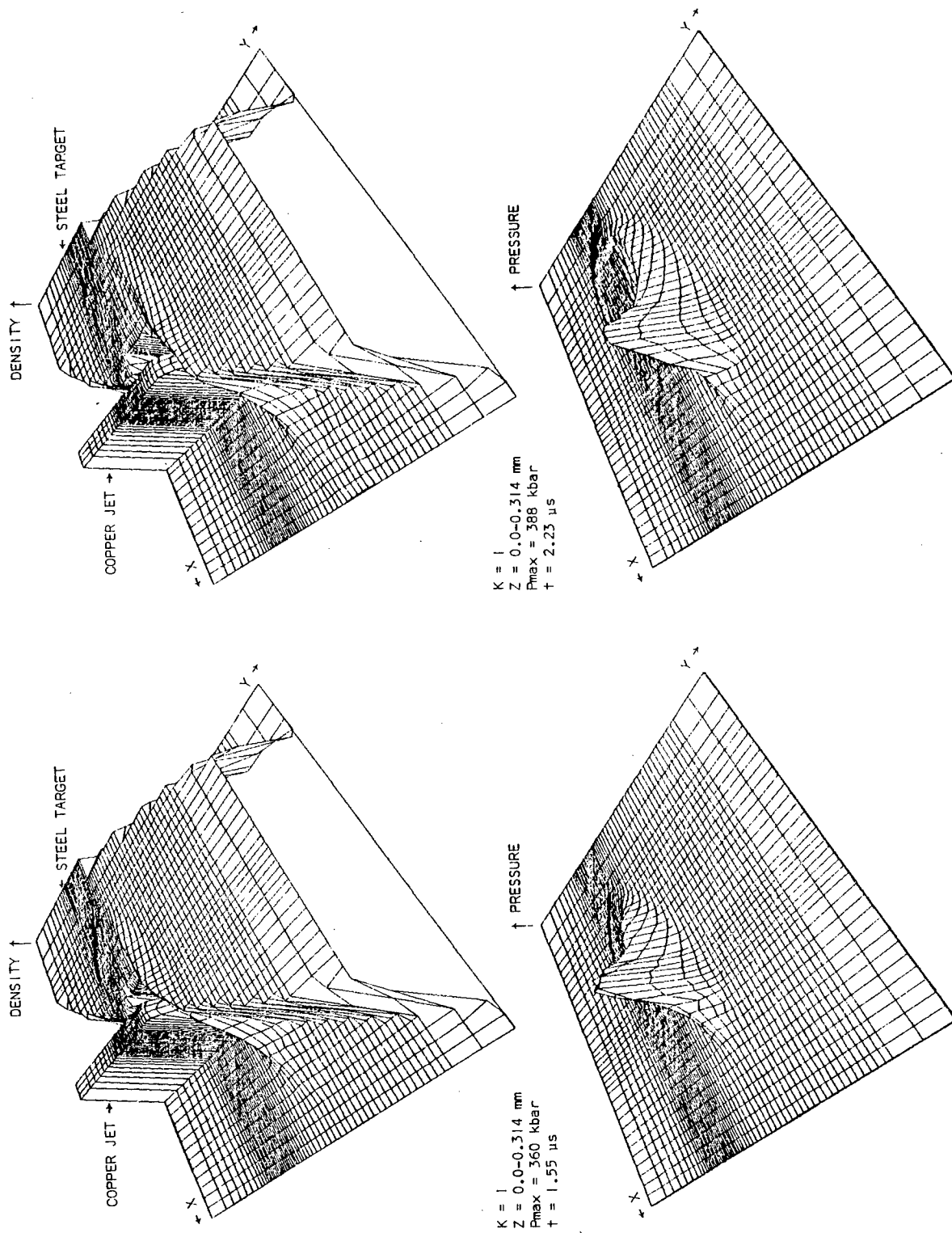
PRESSURE

Figure 60. Density Field and Pressure Field Histories

DENSITY

STEEL TARGET

COPPER JET

K = 1
Z = 0.0-0.314 mm
Pmax = 406 kbar.
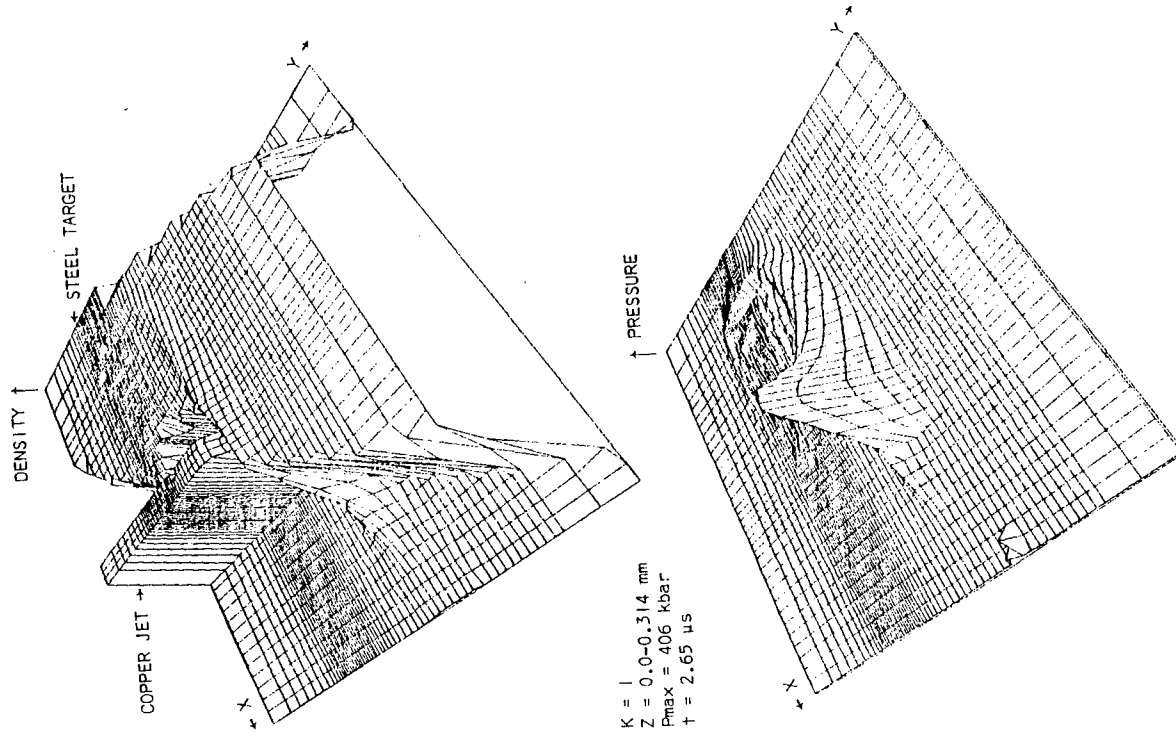t = 2.65 µs

PRESSURE

Figure 61. Density Field and Pressure Field Histories (continued)

71

DISTRIBUTION LIST

No. of Copies	Organization	No. of Copies	Organization

12 Commander
Defense Documentation Center
ATTN: DDC-TCA
Cameron Station
Alexandria, VA 22314

1 Commander
US Army Materiel Development
and Readiness Command
ATTN: DRCDMA-ST
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Commander
US Army Aviation Research
and Development Command
ATTN: DRSAV-E
12th and Spruce Streets
St. Louis, MO 63166

1 Director
US Army Air Mobility Research
and Development Laboratory
Ames Research Center
Moffett Field, CA 94035

1 Commander
US Army Electronics Command
ATTN: DRSEL-RD
Fort Monmouth, NJ 07703

1 Commander
US Army Tank Automotive
Rsch & Development Command
ATTN: DRDTA-RWL
Warren, MI 48090

2 Commander
US Army Mobility Equipment
Research & Development Cmd
ATTN: Tech Docu Cen, Bldg 315
DRSME-RZT
Fort Belvoir, VA 22060

1 Commander
US Army Missile Research
and Development Command
ATTN: DRDMI-R
Redstone Arsenal, AL 35809

1 Commander
US Army Armament Materiel
Readiness Command
ATTN: DRSAR-LEP-L, Tech Lib
Rock Island, IL 61201

1 Commander
US Army Harry Diamond Labs
ATTN: DRXDO-TI
2800 Powder Mill Road
Adelphi, MD 20783

1 Director
US Army TRADOC Systems
Analysis Activity
ATTN: ATAA-SL, Tech Lib
White Sands Missile Range
NM 88002

Aberdeen Proving Ground

Marine Corps Ln Ofc
Dir, USAMSAA

73